Power Transmission Engineering®

SEPTEMBER 2014

MOTION CONTROL ROUNDUP

TECHNOLOGY FROM MDA, IANA AND IMTS

MOTION CONTROL MEETS FORMULA 1
BELT DRIVES REACH FOR THE SKY
HYDRAULICS BEAT THE HEAT

Technical

[Ask the Expert: Breaking in New Axles]

[Evolution of Worm Gear Standards]

[Test Rigs as Part of Wind Turbine Gearbox Development]

[Grease-Lubricated Worm Gears]

Power Play

End Near for "Dear ($$$) Earth" Magnet Motors?

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for Servomotors

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Servo Systems	AutomationDirect Price/Part Number	vs.	Allen-Bradley Price/Part Number
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100W Servo Motor with connectorized Leads	$325.00 SVL-201		$558.00 TLY-A130T-HK62AA
Breakout Board Kit for CN1 Control Interface	$94.00 ASD-BM-50A		$246.00 2090-U3BK-D4401
10' Motor Feedback Cable	$49.50 SVC-EFL-010		$85.70 2090-CFBM6DF-CBAA03
10' Motor Power Cable	$29.50 SVC-PFL-010		$96.40 2090-CPBM6DF-16AA03
Configuration Software	FREE SV-PRO*		$78.10 2098-UWCPRG
Complete 1-axis 100W System	$986.00		$2,284.20

*SureServo Pro software is FREE when downloaded and is also available for $9.00 on a CD

All prices are U.S. list prices, AutomationDirect prices are from April 2014 Price List.
The Allen-Bradley 100W system consists of part numbers shown in table above with prices from www.rockwellautomation.com/en/e-tools 2/20/2014.

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SEPTEMBER 2014

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FEATURE ARTICLES

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TECHNICAL ARTICLES

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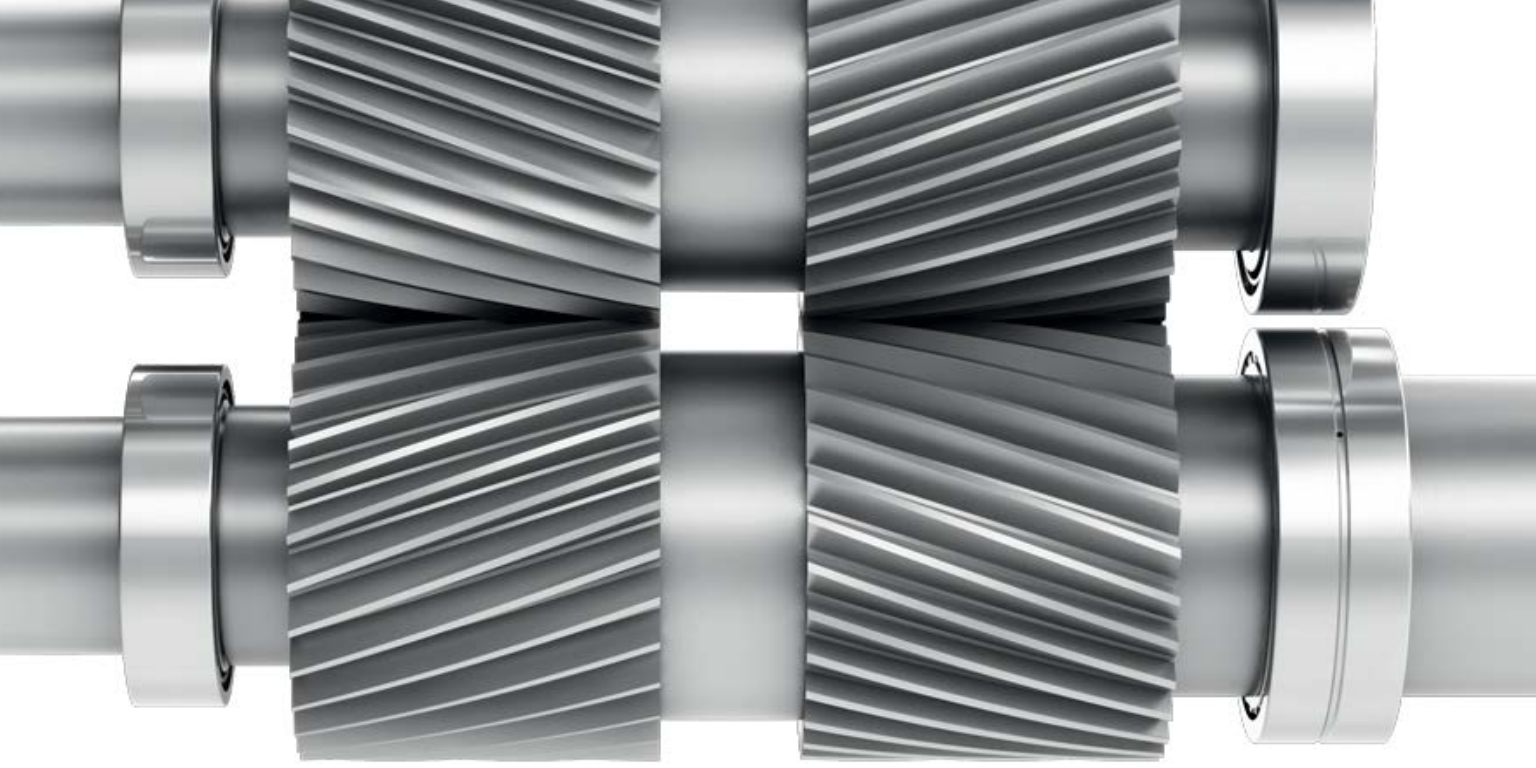
Power Transmission Engineering
VOL. 8, NO. 6

Cover image by David Ropinski



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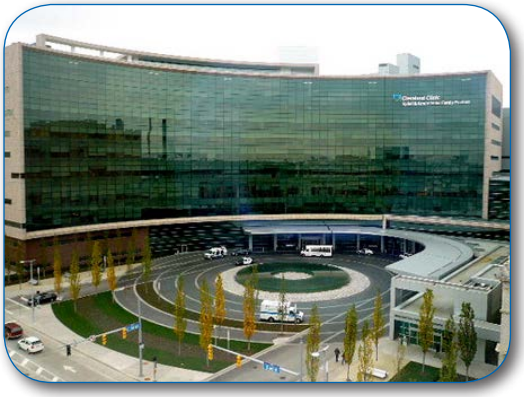
PTE Videos

The Boca Bearing Company is giving away over $10,000 in cash and prizes as part of their 2014 Boca Bearing Innovation Contest. Winners will be chosen based on a video submission of their innovative mechanical project that utilizes ball bearings, roller bearings, linear bearings or any form of full ceramic or ceramic hybrid bearings anywhere in their application *(www.bocabearings.com)*.



Social Media

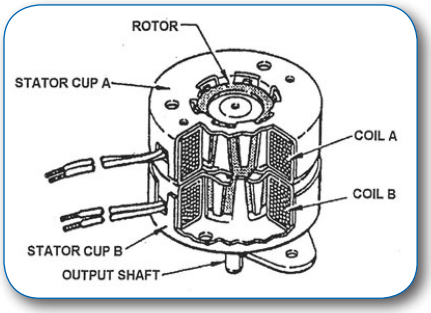
Parker Hannifin Corporation recently announced it is developing more than 100 potential medical advancements with Cleveland Clinic, the noted nonprofit academic medical center that integrates clinical care with research and education. See this and other industry news items on PTE's LinkedIn and Twitter pages.

Management vs. Leadership

You can have great equipment, top-of-the-line tools, adequate supervision and a great design, yet produce nothing but flops if the right people are not in leaders roles. The *Gear Technology* Blog by Charles D. Schultz *(www.geartechnology.com/blog)* recently addressed leadership in manufacturing and what it takes to be a great one.

E-News

Motor guru Dan Jones discusses the latest developments in step motors that are driven by their lower cost motion and position solutions. Read about this and other PT technologies each month in our exclusive E-News features *(www.powertransmission.com/newsletter)*.



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Every day, thousands of power transmission manufacturers around the world rely on precision stock gears produced by Arrow Gear Company.

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Randy Stott, Managing Editor

The Perfect Balance

When we put together the lineup of articles for each issue, we give a lot of thought to balance. Because our readers come from diverse backgrounds and industries, we have to work hard to please everyone. We need technical articles to keep our design engineering audience informed and educated about the state of the art. Our case studies bring the technology down to a more practical level, demonstrating how the best technology is used in a given situation, often from a maintenance or reliability standpoint.

In addition, the world of mechanical power transmission and motion control contains a wide variety of subjects, so we make a concerted effort to cover as many different types of component as possible each issue.

This issue, I'm pleased to say, we have something for everyone, starting with our focus on motion control. Our special product feature presents some of the key motion control technologies that were on display at MDA, IANA and IMTS earlier this month.

We have a trio of case studies that cover unique applications in motors, belt drives and fluid power for the auto racing, elevator and furnace industries, respectively. Thanks to Maxon Motors, ContiTech North America and Bosch Rexroth for sharing these stories with us.

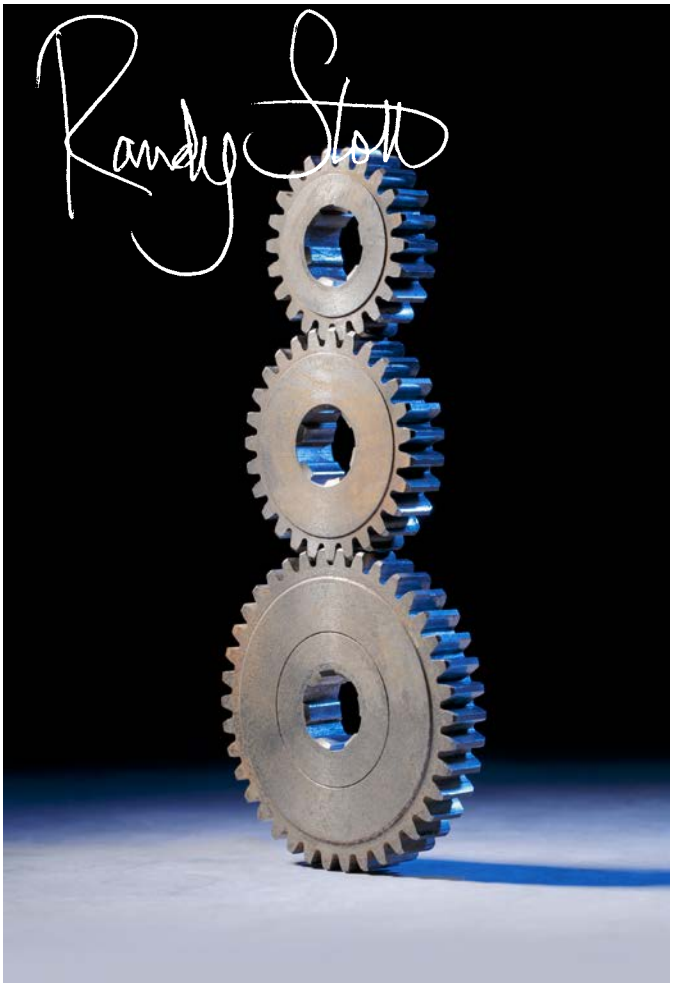
In our "Ask the Expert" column this month, Norm Parker of General Motors explains why new automotive axles require a break-in period. As usual, Norm gives you the technical details that help explain exactly what's going on in the mechanism.

Our three technical articles this issue have a decidedly gear-oriented focus. Dr. Michel Octrue presents an overview of worm gear standards and current best practices for worm gear ratings calculations. Frank Krull explains why and how gearbox test rigs play an important role in the design and development process for wind turbine gearboxes. Finally, a team from the Technical University of Munich has written a study on the load capacity and efficiency of grease-lubricated worm gears.

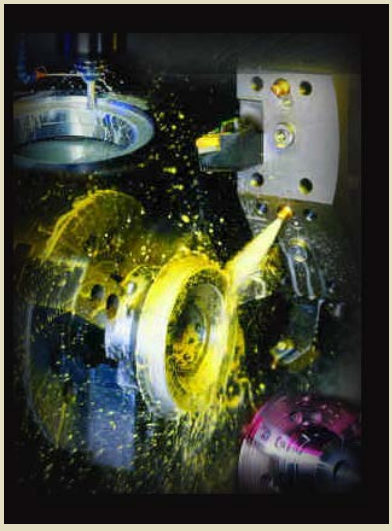
For those of you involved in management, marketing, analysis or business development, I encourage you to read Brian Langenberg's Global Industrial Outlook column. There you'll find insight about which industrial markets are moving in which direction.

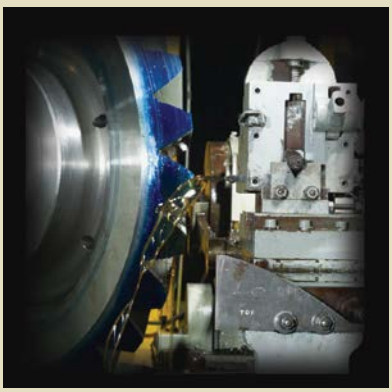
Finally, there are our regular departments, Product News, Industry News and Power Play. The news sections keep you up to date on the latest technology, as well as the trends and happenings related to companies involved in the industry. And you can always count on Power Play for a lighter look at power transmission and motion control.

We're happy with the balance this issue, but it's not ourselves we have to please. It's you, the reader. So don't take my word for it. Read through the issue and pick out the articles of interest to you. Let us know how we're doing, and if you'd like to see some other topics covered in upcoming issues—or better, yet—if you'd like to contribute something yourself, please send an e-mail to *wrs@powertransmission.com*.



CUSTOM
BEVEL GEAR MANUFACTURING





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AGMA

Oriental Motor

INTRODUCES GEARMOTOR CONTROL SYSTEM

A majority of applications need an electric motor to operate at lower speeds (less than 800 rpm). This can be achieved by using a gearmotor. The mating of the fractional horsepower brushless DC motor with the helical gearbox creates a gearmotor that better matches the needs of many factory floor applications. Go one step further and develop the gearmotor with the highest power density performance found in electric motors below 120 watts. Oriental Motor has created a family of small brushless DC gear motors used in the speed control market (Figure 1).

Figure 1 BMU gearmotor and driver.

The Gearbox

The gearbox uses helical gears to achieve reduced audible gearbox noise and simultaneously enhance its torque and speed performance. The gear teeth on the helical gear are cut at an angle to the face of the gear in a helix pattern. The gears, as they move, engage more gradually than spur gear teeth, causing them to run more smoothly and to operate with a much higher load.

Oriental Motor engineering has developed a new family of helical gearboxes to interface with the high-performance BMU speed control system. The gearbox sizes have been developed to match the brushless DC motor's traditional frame sizes but to minimize the gearbox's axial length. Three gearmotor frame sizes constitute the BMU series of gearmotor-based speed controls. They are the:

- 30 watt – 2.36" square by 3.19" maximum combined axial length
- 60 watt – 2.36" square motor, 3.15" square gearbox with maximum combined axial length of 3.78"
- 120 watt – 3.54" square by a maximum combined axial length of 4.52"

Typical helical gear efficiencies range from 93% to 97% depending on the gear ratio.

The wide speed range of the brushless DC motor provides the user with a myriad of gearmotor torque and output speed combinations.

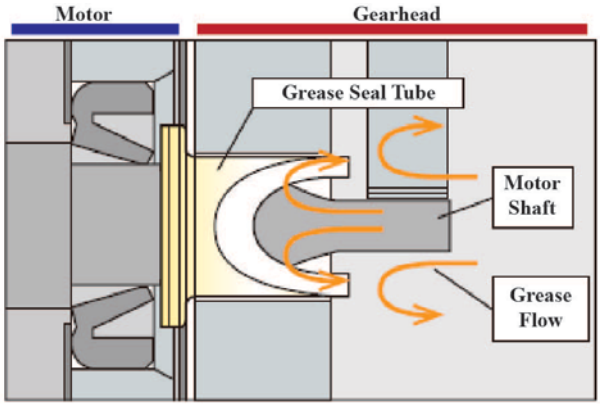

Figure 3 The grease seal tube redirects grease back into the gearbox.

Solving the Grease Problem

The curved gear teeth can provide a "pumping action" of the gearbox lubricant out of the gearbox and sometimes into the motor. The lack of lubricant will cause the gearbox to become noisier. The use of a motor shaft seal will prevent the lubricant from entering the motor. But shaft seals create motor friction torque that reduces overall motor efficiency and output torque. The tighter the seal, the higher the friction torque and the lower the motor efficiency.

Figure 2 BMU motor output shaft, including the new shaft seal system.

Oriental Motor engineering has solved this problem by developing a new shaft seal system (patent pending). The new sealing system is shown in Figure 2. The grease seal tube mounted on the shaft directs the gearbox lubricant back into the gearbox (Figure 3) even before it reaches the motor shaft seal.

The New Brushless DC Motor

The new Oriental Motor brushless DC motor is a completely new design approach. This motor was designed to reduce motor losses, increase motor efficiency, shrink motor size and increase more motor torque and speed performance. The BMU series offers a speed range from 80 to 4,000 rpm or 50:1. Its speed accuracy keeps the speed ripple below 0.2%.

Energy efficiency is a major benefit for this brushless DC motor when coupled with the new driver. A typical 120 watt, 4 pole, AC induction motor and drive can reach a motor efficiency of just 70%, while the 120 watt BMU will top 82.7%. Add a low ratio helical gearbox to the mix and the total 120 watt BMU motor-drive-gearbox system achieves an industry leading 80% near power efficiency level.

For more information:

Oriental Motor
Phone: (310) 715-3300
www.orientalmotor.com

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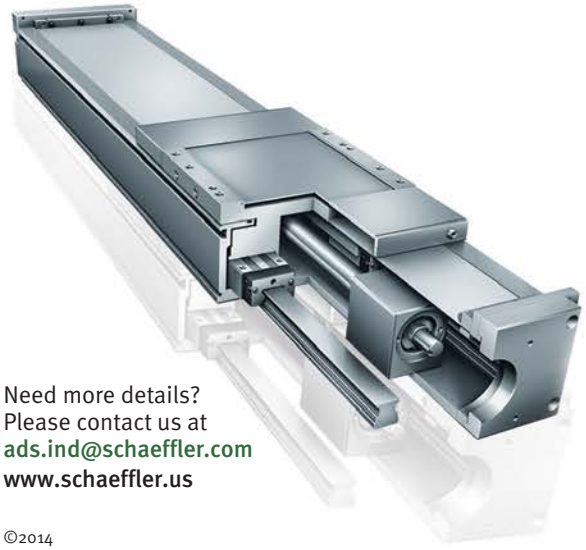
Schaeffler Engineering: Greater Than the Sum of Our Parts

Schaeffler is your source for the industry's most complete line of linear system solutions.

Unrivaled in scope and versatility, Schaeffler's linear product line ranges from shafts with linear ball bearings and monorail guidance systems to sophisticated actuators with drives and control systems, plus special coatings and every conceivable accessory. You name it, we've got it.

But that's only the start. Schaeffler's linear portfolio is based on a modular concept that goes far beyond mere components. We can design a complete system solution tailored to your specific application – from large gantry robots to intricate circuit board inspection systems. In fact, many of our linear guidance systems started out as solutions to customers' needs!



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Klüber Lubrication

INTRODUCES LATEST BEARING GREASES

Klüber Lubrication, a worldwide manufacturer of specialty lubricants, has introduced Isoflex Topas NB 52 and Isoflex Topas NB 152, two rolling and plain bearing greases based on a synthetic hydrocarbon oil and a barium complex soap. The products are suited for amusement industry applications, such as roller coaster wheel bearings, in order to optimize operational reliability, cut servicing costs, conserve energy and extend maintenance intervals. The special barium-soap thickener used in the Isoflex Topas NB 52 and 152 greases offers good load-carrying capacity, as well as resistance to water and ambient media. Both products protect against corrosion, as well as oxidation and aging.

Isoflex Topas NB 52 is suitable for temperatures ranging from –60°F to 250°F and short peak temperatures up to 300°F depending on the application. Isoflex Topas NB 152 can be used in a wide service temperature range of –40°F to 300°F. Isoflex Topas NB 52 is a versatile grease for many applications, including:

- rolling and plain bearings subject to high speeds and loads, as well as low temperatures — ideal for road, side-guide, and up-stop wheels
- tooth flanks in precision gears, such as bevel gears in milling machines and electromechanical actuators for valves
- electric contacts and components to reduce insertion forces

Isoflex Topas NB 152 is compatible with many plastics and is used primarily for medium speed rolling and plain bearings, such as coaster wheels, wheel bearings in racing cars, fan bearings and pump bearings. The grease is also suitable for plastic/plastic or steel/plastic friction points.

"Using Isoflex Topas NB 52 and Isoflex Topas NB 152 greases leads to more consistent torque over a wide temperature range as well as longer component life when exposed to water or aqueous media," said Stephen Mazzola, director of engineering and technical services for Klüber Lubrication North America L.P.

Mazzola recently conducted two training seminars on lubrication fundamentals and advanced lubrication of gears, bearings and chains at the Amusement Industry Manufacturers and Suppliers (AIMS) International Safety Seminar, Jan. 12-17 in Orlando. The AIMS International Safety Seminar is a comprehensive safety-training experience for individuals responsible for the care and safety of the amusement industry's guests.

For more information:
Klüber Lubrication
Phone: (603) 647-4104
www.klubersolutions.com

Curtiss-Wright

SUPPLIES MOTOR CONTROLLERS FOR RACING TEAM

Curtiss-Wright's Industrial division has announced that, via the Lynch Motor Company, it has supplied Sigmadrive motor controllers from PG Drives Technology to Cardiff University's Cardiff Racing Formula Student team.

Lynch Motor Company (LMC) has been designing and manufacturing traction motors and generators for over 20 years and is known globally as a specialist in the field of low-voltage, high-torque permanent magnet DC motors and generators. The company has supported universities throughout the world for many years, and its traction motors have been used for numerous Formula Student (FS) electric-powered vehicles.

Throughout 2013/14, Cardiff Racing has taken its first steps in creating an alternative-fuel Formula Student car with the production of CRT01, a university research project the team intends to enter in the 2015 Formula Student event. This year, however, Cardiff Racing's budget and efforts have been split, with one team continuing the development of an internal combustion powered car for the 2014 FS event and

a second team researching and developing the alternative fuel version.

Whilst much research has been undertaken to prepare the team for the conversion from internal combustion to alternative fuel, one of the greatest challenges has been the development of an electric drive system. However, a breakthrough came when LMC managing director Trevor Lees offered student Matthew Moore a work experience placement during his GAP year between A-Levels and starting at Cardiff University. The work experience drove Matthew to get involved with the FS team when he started University and, having been involved with different universities and FS teams during his twelve-month work experience, Matthew decided to approach Trevor Lees for help during the development program for the alternative-fuel car, and so the relationship started.

Commenting for LMC, managing director Trevor Lees says: "I take great pleasure from working with universities and do what I can to help both students and teams. This can take the form of educational discounts and, in the case of Cardiff University, a presentation I gave on designing and developing electric drive systems, following which I offered advice on the components that can be used within them."

Having designed the drive system for its CRT01 electric car, the Cardiff Racing team approached LMC for the supply of two LEM-200 72 V, 15 kW DC motors and two PG Drives Technology Sigmadrive PMT835M controllers. The four-quadrant Sigmadrive controllers are supplying each LMC motor separately with a CANbus link to produce a differential effect and, like a hybrid vehicle, provide instant acceleration and regenerative braking to put energy back into the batteries. The electric drive system on the CRT01 is capable of providing a peak power output of 28.5 kW and rated torque of 400 Nm at 6,000 rpm.

PG Drives Technology's Sigmadrive PM motor controllers provide smooth and predictable speed control of permanent magnet traction motors across a wide range of system voltages and power ratings. Their advanced design includes features such as IMS technology, high-resolution current measurement, CANbus communications and extremely low heat dissipation. The Sigmadrive PM range can also be configured for dual-traction applications and includes a range of dedicated electric power steer assist controllers.

For more information:
Curtiss-Wright Corporation
Phone: (973) 541-3700
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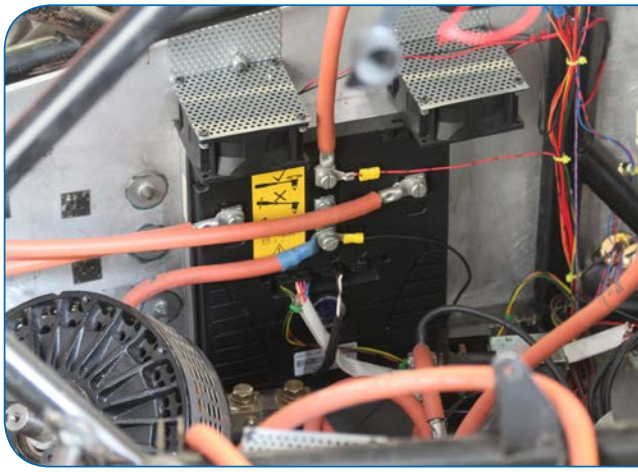

Maxon Motor

INTRODUCES HIGH-SPEED BRUSHLESS DRIVE

The new brushless drive with a diameter of 19 mm has been specially designed for high speeds and features low heat development and extremely quiet and low-vibration running. This little powerhouse has applications in centers for miniaturized processing, hand-held tools and medical technology. When combined with planetary gearheads, many possible variations are available for applications in these key markets.

With its modular construction, this new brushless DC motor is available in three performance classes: the cost-optimized EC 19 at 60 Watt, the strong and high-speed EC 19 at 120 Watt and the sterilizable high-end version EC 19 at 120 Watt.

With Maxon motor's winding technology, it is possible to offer various voltage versions. The stator has been designed without slots. Therefore, no cogging torque occurs resulting in excellent control properties and extraordinarily smooth running. Together with an optimally balanced rotor, low-noise and low-vibration operation is easily achieved.

Maxon's new sterilizable planetary gearhead, the GP 19 M is suitable for applications requiring very high speeds – input speeds of up to

40,000 rpm. To accommodate such high speeds, the toothing and materials have been especially designed to minimize friction. A key demand placed on the material is 1,000 sterilization cycles. The gearhead contains a special shaft seal. Worth noting is the no-need to disassemble the drive unit for the sterilization process. The new 19 mm drives are particularly suitable for surgical and dental devices, such as arthroscopic shavers and bone drills. There is also a focus on respirators and CAD/CAM spindle drives.

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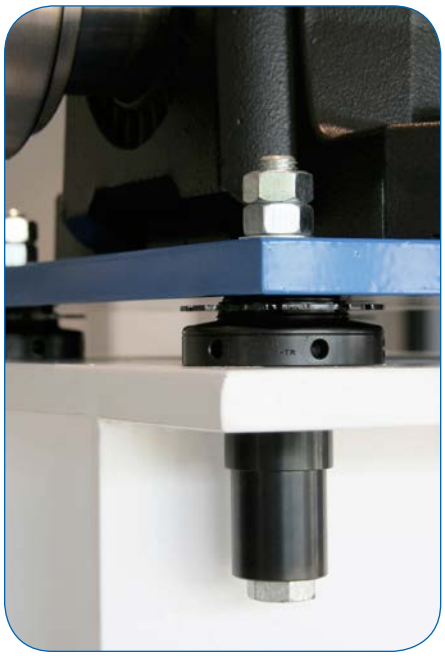

all other heavy-duty bolted joint applications. The all-spherical two-piece washer automatically adjusts under compression to compensate for up to four degrees of angular deviations. This creates an exact parallel plane between the inner face of the bolt head and inner face of the nut to distribute the load evenly over the entire inner contact surface areas. Any need for on–site machining (spot facing) to achieve parallelism is eliminated.

SKF Spherical Washers ultimately serve to reduce the likelihood of bolt relaxation by distributing bolt tension evenly, retaining proper bolt tension by preventing bolt bending, and keeping bolts straight as intended. The extended length of the spherical washer allows for the use of longer bolts, resulting in additional bolt clamping length and elongation in the bolt.

These two-part spherical washers incorporate a larger ring with a concave surface, which connects to its corresponding smaller convex piece to achieve application benefits, such as an enlarged contact area with a reduced surface contact pressure. All washers are manufactured from high-grade alloy steel and feature a special surface treatment to enhance corrosion protection in humid, salty, and other corrosive or harsh environmental conditions.

Versions available for quick turnaround and delivery include Type SW standard height (60 mm or 2.36 in.), which users can easily machine down for lower washer heights as necessary, and Type SWLP low profile (20 mm to 34 mm or 0.79 in. to 1.34 in.). In addition to the stocked product line, custom spherical washers can be ordered (including the opportunity to specify alternative materials).

For more information:
SKF USA Inc.
Phone: (267) 436-6000
www.skfusa.com

Taylor Hobson

OFFERS BEARING MEASUREMENT TOOL

A precision surface measurement tool featuring an industry-leading high-speed column drive, precision positioning and 4 mm roundness and contour gauge has been introduced

by Taylor Hobson, a unit of Ametek, Inc. The new Talyrond 500H measures roundness, profile and surface finish on a single platform with high accuracy due to an extremely low noise floor. It is ideally suited for high-accuracy measuring applications including precision bearings, fuel injectors, crankshafts and turbocharger parts. Numerous specialized accessories allow the instrument to accommodate the industry's most demanding applications.

It accurately duplicates a machine tool's movements and exactly reproduces a work piece shape. This allows the Talyrond 500H to provide users with rapid feedback for efficient quality assurance. A low-noise metrology frame, accurate axis alignment and a patented data collection method provide it with unmatched straightness and roundness measurement capabilities. A high-resolution gauge measures linear or circumferential surface roughness. A frictionless air-bearing spindle and precision column measure roundness, cylindricity and straightness. A patented calibration technique performs radius, angle, height, length and distance measurements.

Simplified teach and learn programming techniques, comprehensive user prompts and on-screen instructions combine for easy, error-free operation. It performs calibration, center and level functions along with measuring routines automatically.

For more information:
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Phone: +(44) 116 276 3771
www.taylor-hobson.com

Heidenhain

EXPANDS ROTARY ENCODER SERIES

Heidenhain is expanding its third generation of absolute inductive rotary encoders with the ExI 11xx series, providing a single encoder safety solution for many industries such as packaging, automation and robotics. These new products are especially suitable for safety-related applications up to SIL 3, PLe, and Category 4. These applications involve high risks for the operator such as when they may interact with a robot.

The ECI 1119 and EQI 1131 each feature an increased single turn resolution of 19 bits while the EQI 1131 can track 4096 (12 bits) revolutions. The ECI and EQI encoders showcase improved vibration specifications (400 m/s2 stator and 600 m/s2 rotor), as well as a more durable multi-turn gearbox, and an increased permissible axial motion of the shaft up to ±0.4 mm. These encoders also have the advantages of previous bearingless, inductive encoders which include the non-contact de-

sign, resistance to contamination, no mechanical self-heating, and reduced sensitivity to radial runout.

The ExI 11xx series joins the ExI 13xx encoders as the new generation of Heidnehain encoders that feature functional safety and improved robustness. These encoders offer a host of different safety related functions that can be upgraded even further with the implementation of safe control that supports the EnDat Safety Master. These additional measures can be implemented independently of the control loop parameter. This allows the safety measures available to work directly with a controls safety module, without being affected by changes in control-loop parameters.

For more information:
Heidenhain Corporation
Phone: (800) 233-0388
www.heidenhain.com

J.W. Winco

RELEASES STAINLESS STEEL HANDWHEELS

J.W. Winco, Inc., a supplier of standard industrial machine components, announced it now offers GN 227.4 A4 stainless steel spoked handwheels, in inch and metric sizes, with and without revolving handle.

These RoHS-compliant handwheels, often used where a noncorrosive component is necessary, such as the marine and food industries, are renowned for their high mechanical strength and are not affected by shock and knocks. They are of an attractive design and shape at a reasonable cost.

Handwheel body is pressed A4 (AISI 316L) stainless steel, with a shot blast satin finish. Solid hub is also made of A4 (AISIS 316L) stainless steel, welded to body. Inch size versions are available with round bore without keyway. Metric sizes are offered with round bore without keyway, round bore with keyway, and square bore. Various additional bore sizes, keyways, set screw holes are also available upon request. Diameters range from 160 to 400 mm (6.3 to15.74 inches).

J.W. Winco offers an extensive selection of inch and metric size adjustable levers, cabinet U-handles, plastic and steel hinges and locking mechanisms, revolving and retractable handles, hand wheels, hand cranks, tube connection and conveyor components, and more.

For more information:
J.W. Winco
Phone: (800) 472-0670
www.jwwinco.com

Bosch Rexroth

DEVELOPS SMART CONTROL IN AUTOMATION

In the future, mobile devices like smartphones and tablet PCs will conquer offices and production halls of modern companies. With the help of these devices many processes can be simplified and made even more efficient. Glaub Solution GmbH situated in Salzgitter, Germany, develops HMI solutions which can be used to operate complete automation systems from smart devices by means of apps.

The systems are based on Open Core Engineering with Open Core Interface technology as well as the controls IndraMotion MLC and IndraLogic XLC from Rexroth.

Since 2012 Glaub Solution GmbH in Salzgitter has been working on a native app for controlling automation systems. The solution that is suitable for Android and iOS devices allows today operation and diagnostics for a three-axis system via smartphone and tablet PC.

First attempts to connect apps via OPC servers to the PLC were not sat-

isfactory with regard to performance and flexibility. Finally, Glaub found an efficient way to develop the ECO/App SmartControl using Open Core Engineering – without the need for additional hardware or software licenses. "Open Core Engineering from Rexroth gave us the opportunity to realize controlling independently of IEC programming, because we can directly intervene into the control core of the PLC – with an effort of only a few hours," explains Niko Glaub, managing director of Glaub Solution GmbH.

The solution by Glaub demonstrates how easily and quickly numerous functions can be implemented with Open Core Engineering. The access to PLC variables, to axis functions and the diagnosis log can be realized comfortably in high-level languages (C++, Objective-C or Java) using the function libraries of Open Core Engineering. And this can be accomplished within a minimum of time: After having configured the PLC with the Rexroth engineering tool IndraWorks, Glaub merely had to add the headers and the library files from Rexroth into the project. For this, Rexroth offers, for example, libraries with more than 500 ready configurations.

The result: In the case of the ECO/App SmartControl, a toolbar on the side of the screen allows direct access to the most important menus. Apart from gesture control, the user can utilize the motion sensors of the mobile device: The axes of the machine move towards the direction, to which the user tilts his tablet. The tilt angle determines the speed of the movement. Unlike conventional, stationary operator devices, smart devices that communicate over WLAN offer the user a significantly higher degree of flexibility.

"With Open Core Engineering from Rexroth we can create optically attractive user interfaces for machines which don't discourage their use, but are fun," says Glaub. "With this solution, Rexroth pushes the door to Industry 4.0 wide open."

For more information:

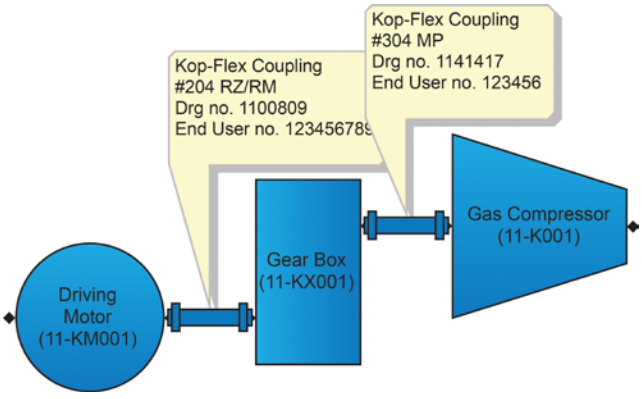
Bosch Rexroth
Phone: (800) 739-7684
www.boschrexroth.com

Glaub Automation & Engineering GmbH
Phone: +(49) 53 41 86 39-0
www.glaub.de

Emerson

OFFERS ONLINE TRACKING TOOL FOR COUPLINGS

Emerson's Power Transmission Solutions introduces industry's first online tool for tracking the location, life history and latest revision drawings and installation instructions for all critical drivetrain couplings owned by customers, whether installed or in spares inventory. Developed by Emerson's Kop-Flex business unit, the web-based tool, known as the Asset Management Program (AMP) for couplings, accurately identifies couplings, graphically displays the location in a specific drive, identifies parts/couplings at the site that are interchangeable, makes assembly drawings a click away and gives a detailed service history and action to be taken during service intervals. The Coupling AMP will be introduced and demonstrated at the Turbomachinery Show, September 22-25, in Emerson's booth 1231. The demonstration site is available at *http://amp.emerson-ept.com*, with the login and password of "turbouser." Users can see two plants and two rotating equipment assemblies in each, with sample data.



Developed by a worldwide engineering team experienced in coupling design, maintenance, repair and troubleshooting, the Coupling AMP provides in-depth information on components critical to the operation of major systems such as compressors, turbines or pumps. "Plant engineers plan shutdown maintenance with tight timeframes, yet they struggle to identify couplings by make, model, serial number, stock code, manufacturer's part number, etc.," said Parimal Deshpande, senior industry specialist for Kop-Flex. "Adding to this disorganization are emergencies. Engineers may take parts from new or old couplings and use them in repairs. This is not only bad practice because of balancing issues, but it makes it almost impossible to track where all these parts went, and what's been stripped from old or new couplings, etc. In a couple of years, they have no idea what's happening. Moreover, it's very difficult to track the service history of couplings. Customers told us there's no commercially available software designed with a friendly, useful system to organize the needed information the way they'd like to access it. Coupling AMP addresses this void."

Coupling AMP has been carefully built to categorize, display and log information in the exact same way that plant engineers already visualize it. "Engineers sometimes identify couplings by serial number, assembly drawing number or their own stock code," explained Joe Corcoran, manager, global services and training for Kop-Flex. "For them, we have a search function. More commonly, rotating equipment engineers know the exact location of a coupling by heart, and for these cases there is an 'Equipment Overview' which is the first page after login."

Coupling AMP's custom graphics display specific drive configurations for rotating equipment. By clicking on a coupling, AMP opens a "coupling card" with all related information, such as end-user stock code, serial numbers, OEM part numbers, Kop-Flex part numbers, location of spares or interchangeable parts, bill of material, latest revisions of the assembly drawing, installation instructions and service history. The system also maintains records on customer training, trouble-shooting analyses, service reports, and more in a history associ-

ated with a specific serial numbered coupling. This information is available 24/7 on the Internet.

Coupling AMP is a subscription service maintained by Emerson. It begins with a survey of a customer's site by a Kop-Flex representative where all relevant data is collected. Kop-Flex then populates AMP and provides a user name and password to the customer. Edits and additions are handled via e-mail to Kop-Flex.

For more information:
Emerson Power Transmission
Phone: (800) 626-2120
www.powertransmissionsolutions.com

Ruland Manufacturing

UTILIZES BEAM COUPLINGS FOR MEDICAL APPLICATIONS

Ruland beam couplings are zero backlash, have high torsional stiffness and accommodate misalignment, making them well suited for encoder, tachometer and light duty power transmission applications commonly found in medical equipment. They offer low inertia, light bearing loads, and a balanced design for reduced vibration at higher speeds.

Ruland beam couplings utilize two sets of overlapping spiral cuts to increase torque capabilities and torsional rigidity when compared to the commodity style single beam coupling. Separating the spiral cuts into two sets gives the coupling better parallel misalignment capabilities while easily accommodating angular, complex, and axial misalignment. Zero backlash beam couplings are ideally suited for test and measurement, robotics, imaging, patient positioning, liquid chromatography, and lab analysis equipment which require accuracy of motion.

Ruland beam couplings are available with four or six beams in inch, metric, and inch to metric bore combinations ranging from 3/32" (2 mm) to 3/4" (20 mm). Four beam couplings are more flexible with lower bearing loads while six beam couplings feature a larger body size with shorter spiral cuts to provide increased torque capability, repeatability, and torsional stiffness. Multiple beam couplings are available in aluminum for additional flexibility and low inertia, or in stainless steel for higher torque and increased corrosion resistance. Special dimensions, spiral cut patterns, finishes, and materials are available by request.

Beam couplings are part of Ruland's complete zero backlash coupling line which includes rigid, beam, bellows, disc, jaw, and oldham types. All couplings are manufactured in Ruland's Marlborough, Massachusetts factory and are RoHS2 and REACH compliant.

For more information:
Ruland Manufacturing Co., Inc.
Phone: (508) 485-1000
www.ruland.com

Zero-Max

DESIGNS LARGER ETP TECHNO SHAFT BUSHINGS

New, large size ETP Techno shaft locking bushings are now available for bore sizes of 110, 120 and 130 mm (4.330, 4.724 and 5.118 inches) from Zero-Max. They are designed for locking components to large shafts with repeatable precision for applications requiring frequent mounting operations. They are suitable for locking into position gears, pulleys, sprockets and other components in automated machinery.

Handling torque ranges from 247,820 inch lbs. to 283,223 inch lbs. (28,000 to 32,000 Nm), these ETP Techno shaft locking bushings from Zero-Max provide the highest radial load performance within the ETP radial actuation screw product line.

For more information:
Zero-Max
Phone: (763) 546-4300
www.zero-max.com

Stafford Manufacturing

OFFERS LATEST SHAFT COLLARS

A line of lever-actuated hinged shaft collars now offered with a mounting flat to create high-strength, quick-change pipe mounts and pipe hangers has been introduced by Stafford.

Staff-Lok Hinged Shaft Collars feature an integral hinge with a conformal cam lever for clamping and a knurled nut for adjusting the clamping preset, which makes it easy to open-close and clamp by hand. Now offered with a mounting flat with a countersunk hole and attachment screw, they are ideal for securely mounting pipe and tube requiring frequent or fast changes.

For more information:
Stafford Manufacturing Corp.
Phone: (800) 695-5551
www.staffordmfg.com

Value Added at MDA, IANA and IMTS

Smart Manufacturing Highlights PT Focus in Chicago

Matthew Jaster, Senior Editor

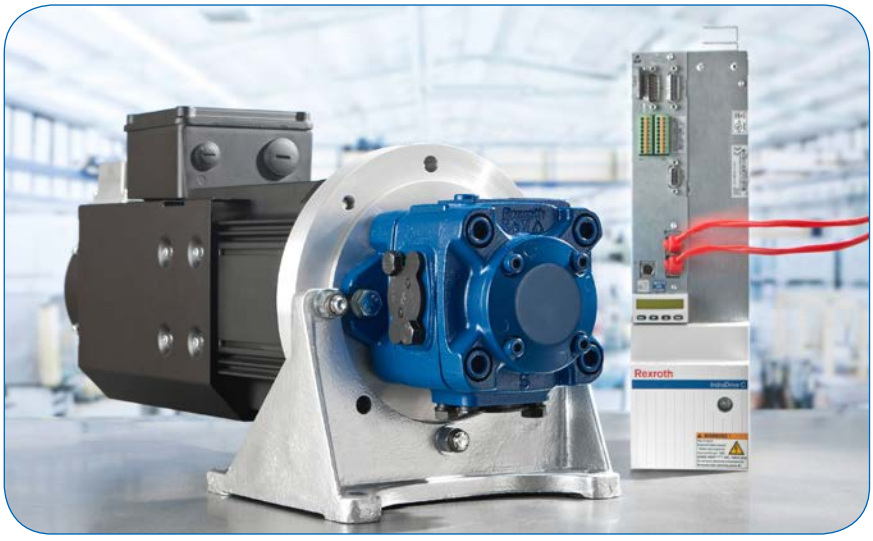
What was once targeted specifically toward the machine tool and metalworking industries, IMTS 2014 in Chicago spent a great deal of time and resources on automation, controls, mechanical components, self-diagnostics and an increase in productivity on the shop floor. Smart manufacturing is all the rage, following Europe's push for an intelligent factory that integrates customers and business partners into the manufacturing process via the latest technologies.

This is why the Industrial Automation North America (IANA) show expanded in 2014 and why Motion, Drive and Automation North America made its debut. IMTS now delivers some of the latest innovations in automation, power transmission, motion control and fluid technology. Here's a few of the highlights from the show:

Bosch Rexroth

Bosch Rexroth exhibited a broad range of automation products and systems for improving productivity and energy efficiency, as well as safety and training in machine tool and CNC applications. Visitors to the booth at IMTS participated in a demonstration that highlighted the flexible programming abilities of Bosch Rexroth's Open Core Engineering system. They were also treated to a real-time machining visualization on a handheld tablet connected by wireless Ethernet that demonstrated real-time machining monitoring, one example using the innovative Open Core Interface with the IndraMotion MTX CNC platform. In addition, the company showcased its IndraMotion MTX CNC family of machine tool controls. These provide open, scalable, CNC platforms for cutting, forming and machining applications. The newest platform version features the multi-core hardware CML 85, which supports 60 parallel NC-channels and control of up to 99 axes (up from 12 channels and 64 axes). In addition, the machine builder using IndraMotion MTX can now take advantage of simplified wiring of safety devices by using CIP Safety on Sercos (CSos) with the IndraDrive and PROFIsafe over Profibus DP.

For more information:
Bosch Rexroth
Phone: (800) 739-7684
www.boschrexroth.com



ABB

ABB Robotics featured more than ten advanced technology demonstrations at IMTS including new robots, turnkey manufacturing cells, and enhanced technology designed to increase manufacturing productivity for operations of varying sizes and industry sectors. The IRB 1200 Robots provide an entirely new small robot family that provides flexibility, ease of use, short cycle times, and a unique combination of a compact footprint and a large work envelope. It is designed for a wide range of material handling, machine tending and small parts assembly applications.

The FlexMT is a flexible, pre-engineered system designed to load and unload machine tools using vision guided robotics. Designed for both small batch and high volume production, the FlexMT increases spindle utilization by up to 60% over manual machine tending. The system can handle most any size and type of part, and is compatible with a wide range of machine tools, including horizontal and vertical lathes, machining centers, five-axis machines and grinders.

ABB's High Speed Industrial Part Handling Cell demonstrates the capabilities of the higher payload 6 kg and 8 kg IRB 360 FlexPicker robot models, bringing the fast cycle time pick-and-place performance used in the food and pharmaceutical markets to heavier-part industrial applications. The cell features ABB Integrated Vision, capturing accurate part locations for pick-up and set-down; and a Servo Gripper that allows the handling of multiple part sizes with a single gripper. The FlexPicker is the most widely used delta robot in the industry, with over 6,500 installations worldwide.

The Robotic Bin Picking Cell is designed in collaboration with Midwest Engineering Systems Inc. (*www.mwes.com*), an ABB Value Provider. The cell, which features an ABB IRB 4600 robot, combines *SICK PLB 3-D* vision for the

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motion control
at www.powertransmission.com

precise localization of randomly orientated parts in bins and boxes, with gripper accuracy that allows the parts to be placed in known orientations and positions. The cell features *ABB RobotWare* software and *SICK* bin picking software, integrated in the IRC5 robot controller for simplified programming and operation. MWES, headquartered in Pewaukee, WI, provides custom machines, integrated systems, and automation/robotic solutions to manufactures around the world.

ABB's CNC Machine Tending Cell designed by VersaBuilt (*www.versabuilt.com*), uses vise soft jaws to move parts in and out of the CNC machine, with no custom robot programming or robot fixturing required. The soft jaws enable a new tended part to be setup in approximately 10 minutes, with the system able to run unattended for 24 hours.

The IRB 6700 Robots includes one model in material handling dress and two models dressed for spot welding. The material handling robot is simulating load, unload and part presentation for the welding robots. The spot welders feature Spot Servo Equalizing, which allows spot welding gun equalization without mechanical equalizing hardware, reducing the investment cost and improving productivity. The IRB 6700 is available with LeanID, a new Integrated Dressing (ID) designed for easier programming and a smaller footprint. It has also been built to withstand the harshest working environments and is available with ABB's ultimate Foundry Plus 2 protection system. In addition to enhanced speed, payload and accuracy, the power consumption has been lowered by 15%, total cost of ownership has been reduced by up to 20%, and maintenance has been optimized, doubling the time between service intervals.

For more information:
ABB
Phone: (919) 856-2360
www.abb.com

Sercos International

Sercos International, supplier of the Sercos automation bus, presented a multi-vendor interoperability demo at IANA in Chicago, IL,The multi-vendor interoperability demo displayed various automation products connected using the Sercos automation bus including the Bosch Rexroth XLC (eXtended Logic Control) PLC, IndraDrive Cs servodrive, various IO devices (Inline, S20, S67 and VAM panel), SafeLogic compact safety control, and HNC100-3X hydraulic axis controller. Additional Sercos devices included an Aventics pneumatic valve system, Cannon-Automata SSI Gateway for Encoders, Feller Engineering's multi-channel temperature controller, Festo's pneumatic valve terminal, a halstrup-walcher positioning system, RiceLake's Laumas Load Cell Transmitter and a TR-Electronics programmable absolute encoder. Cannon-Automata presented a demo of the new A2 PC based-Intel Atom dual core equipped Programmable Automation Controller. The A2-PAC device family combines the advantages of a PC-based control with the typical features of PLCs and motion controllers. Also on display was Bihl+Wiedemann's AS-i 3.0 Sercos Gateway with integrated safety monitor for CIP Safety on Sercos, which can be used to transmit data from safety input slaves and to safely control safety output slaves via CIP Safety. Peter Lutz, managing director of Sercos International, presented "Trends in Industrial Communications for the Factory of the Future."Part of his presentation was on the blended infrastructure conceptual approach that simplifies the integration of machinery in manufacturing. True to the slogan "Fewer cables, less complexity, easier machine integration," Sercos International developed this approach in collaboration with ODVA and the OPC Foundation. A common network infrastructure where Sercos telegrams, EtherNet/IP messages, CIP Safety messages and TCP/IP telegrams run on one single cable.

For more information:
Sercos International
Phone: (800) 573-7267
www.sercos.org

Nachi Robotic Systems Inc.

The MZ07 robot series features ultra-high-speed motion capability with advanced through-arm dress capabilities to simplify routing of hoses and cables for material handling, assembly, vision and many other applications. Through arm cabling minimizes interference and potential snags with peripheral objects in your work cell, helping to protect pneumatic and signal cables from damage. Boasting an IP67 rating, the MZ07 robot boasts a 0.31 second cycle time in standardized speed testing, leading all competitors' robots. Flexible mounting solutions allow the MZ07 to be floor, wall, or invert mounted to better suit customers' needs for any given application. In addition to being the world's fastest articulated robot, the MZ07 offers the largest working envelope in its class at 723 mm with an impressive repeatability of ±0.02 mm. The MZ07L extends the usable work space up to

912 mm. The MZ07 and MZ07L offer full 6-axis articulation while the MZ07P and MZ07LP are specially designed for palletizing applications featuring a five-axis design to simplify teaching palletizing routines by eliminating the J4 axis. In addition to Nachi's comprehensive robot lineup, the MZ07 builds on the great heritage of large payload robots by providing an extremely versatile small robot with top of the line capabilities.

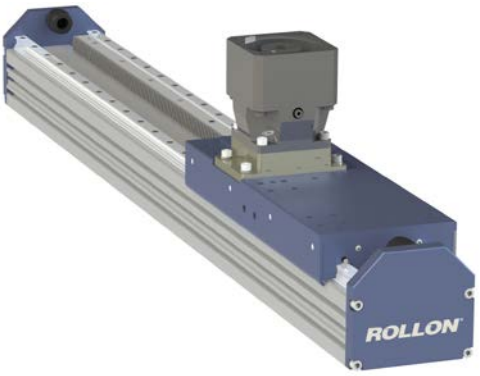
Additionally, Nachi continues to develop advanced robotic spot welding solutions – focused on making higher quality welds more quickly than in the past. With advanced industry leading hollow arm technology, the SRA-H series robots simplify cable routing by eliminating the need for external dress packages. Nachi's advanced hollow arm design improves cable life and neatly packages all pneumatic, power, and servomotor cables for turnkey success. Specifically designed for the fast paced automotive industry, SRA-H series robots will dramatically reduce cycle times, significantly improve productivity, and achieve cost reduction.

The SRA series robots and their FD controllers are suited to spot welding applications. The SRA-H robots are highly rigid and weight less, providing faster motion and less vibration. Advanced motion control from the FD controller provides top acceleration thereby shortening cycle-times. The FD also has 4th generation servo gun control software enabling higher motor speeds while maintaining gentle electrode contact to parts, optimizing spot welding performance. Finally, Nachi together with welding partners (Obara and Art Hikari), are pushing the envelope in resistance welding with lightweight modular guns and spot welding solutions for aluminum parts.

For more information:
Nachi Robotic Systems Inc.
Phone: (248) 305-6545
www.nachirobotics.com

Rollon Corp.

Rollon has been providing linear bearings, actuators, and linear motion products across a wide variety of industries including plant assembly, packaging design, transportation manufacturing and medical device development. The company unveiled its new rack and pinion for vertical applications and long strokes at IMTS 2014. Rollon Corp's new R-Plus System rack-and-pinion actuator delivers consistent rigidity and high axial forces throughout its stroke. The R-Plus is attached to a robust 160- or 200-mm wide aluminum alloy beam with single piece long lengths that permit large loads with minimal deflection. It supports multiple carriages and associated pinions on the same axis, with each carriage capable of independent motion. The actuator is also effective in vertical applications and comes pre-installed with a precision speed reducer ready to mount the motor of the users choice.

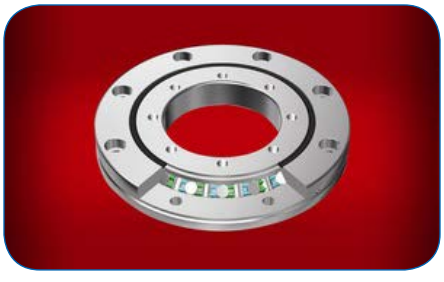


The R-Plus System has self-sustaining aluminum extrusion profiles that house profile rails with recirculating ball bearings for large and balanced load capacity. The units are operated by hardened, tempered and ground steel rack and pinion helical teeth gears and a built-in lubrication kit allows the pinion to be easily greased for smooth operation and long life.

For more information:
Rollon Corporation
Phone: (973) 300 5492
www.rollon.com

THK America

THK aims to contribute to the improvement of industry by focusing on toughness, high-quality and know-how in areas like ball screws, lifting equipment, lubricants, robots, slides, linear guides and more. During IMTS, THK offered its latest Caged Ball LM Guide models SPR/SPS and SVR/SVS used in the machine tool industry as well as other motion solutions including ball screws, actuators and cross roller rings.



For more information:
THK America
Phone: (847) 310-1111
www.thk.com

Neugart USA Corp

German gear technology products manufacturer that believes in modern CAD and manufacturing processes to create high quality and precise products including gearboxes, bearings, clutches, gears, v-belts, gear reducers, etc. This year, Neugart presented the latest version of the *NCP* (*Neugart Calculation Program*), the design software for the entire powertrain. With the new version *NCP 3.0* new applications are implemented, such as the center winder and the contact or surface winder. Furthermore the product lines

PSN and PSFN are now also available in the design sizes 142/190 (PSN-helical geared shaft gearbox) and 140/200 (PSFN helical geared flange gearbox). A new concept for motor and gearbox selection was implemented and offers now many new features to make the selection of the matching components even easier. Convenient filtering and sorting options are used. With *NCP 3.0* it is also possible to sort according to operating efficiency or running noise. To offer the opportunity to dimension the gearboxes even more accurately, it is now possible to determine the gearbox losses as a function of gearbox temperature, torque and speed for any time.

For more information:
Neugart USA Corp.
Phone: (757) 340-5551
www.neugartusa.com

Mach Motion

What began as a father and son retrofitting machines has expanded into designing and fabricating CNC controls, offering CNC software and providing retrofitting, rebuilding and remanufacturing services. Quality is the goal at Mach Motion where engineers want anyone to retrofit or build machines without a lot of electrical CNC know-how. The company is developing controls and products of the "plug-n-play" variety. Mach Motion had a presence at two booths at IMTS including Yaskawa America and SolidCAM. The company provided information that will allow attendees to add the latest CNC technology to their existing machines. The company also held a raffle to win a free control on a machine eligible for retrofit in the Continental United States.

For more information:
Mach Motion
Phone: (573) 368-7399
www.machmotion.com

Full Throttle

The Formula Renault 3.5 is seen as a crucial stepping stone on the way into the premier class, the Formula 1. Ambitious racers do not just bring their talents – they also have Maxon motors on board to control the throttle of their 530-hp V8 engines.

Andreas Turner, Maxon Precision Motors

Nico Müller is a professional race car driver from Switzerland (all photos courtesy of Maxon).

Top gear. 160... 170... 180... 185... The back of Nico Müller's neck is pushed against the edge of his bucket seat under the pressure. Strangely, it does not relent even after reaching the top speed of 193 mph. The 21-year-old executes the required steps as if in an oxygen intubation: inhale, exhale, raise shoulders, drop shoulders, all with exaggerated slowness to ride out the adrenaline rushes.

Exploding fuel vapors

The tachometer shows 9,000 rpm as the pistons of the V8 rip a torrent of fresh air through the fully open throttle flaps. In the cylinders, fuel vapors detonate in controlled explosions, delivering brutal acceleration. A sharp bend, initiated with a quick dip of the left foot on the brake pedal, causes a centrifugal pull on tires, suspension, chassis, and neck muscles. And yet, the car cuts smoothly along the track in the midst of a lush green area interspersed with a few trees. The one-seater purposely winds its way through the Royal Park in Monza, past the Milano Golf Club. The down pressure from wings and diffusors now exceeds the weight of the Formula Renault 3.5 car – strong enough to activate the natural laws of compression. Under the heat of the load, the steering seems to have merged into a unit reaching all the way up into the driver's shoulders. The carbon brakes could hurl Müller into his harness with a force equal to three times his own weight.

Maxon motors and gearheads provide innovative technology for racing applications.

Fine tuning

The pit stop at Draco International Racing in the Autodromo Nazionale di Monza: "We nailed it this lap, the car felt great on every section of the track," Müller says. He flashes a relaxed smile. Before the actual lap time was announced, the young man from the Bernese Oberland knew instinctively that he would appear in the upper reaches of the provisional ranking. As he turns to walk off towards the shower, he lets the pit master know where the set-up of the 610 kg Zytek-powered Formula Renault could use some fine tuning.

"We are working on the details of the adjustable rear wing and the pedal mapping, even if we gain less than one tenth of a second per lap in the end," says Draco Team Manager Simone Giglio. He explains how the characteristic fields of the accelerator pedal, the so-called pedal maps, affect the performance and drivability of the engine. "It is always about the relationship between speed and accelerator

position. Thanks to drive-by-wire, the electronic throttle control, this can be defined in almost any way." Even some serially manufactured sports cars today are using this technology to provide a more dynamic characteristic as an option. Drivers can choose a more direct response from the engine. It becomes quicker and feels more like a racing unit.

Butterfly throttles

The Zytek engines used in the Formula Renault 3.5 are equipped with so-called butterfly flaps that are mounted on a rotating axle. At full throttle, the flap is vertical, offering no resistance to the air flowing into the cylinder. To close, it rotates into a horizontal position and interrupts the air flow. The precise control of the Zytek throttle system is handled by a Maxon RE-series DC motor and planetary gearhead. All eight flaps are connected with a single mechanism. They open and close in only 10 to 15 milliseconds — comparable with the flash of a camera. On a high-speed racetrack like Monza, the car is at full throttle about 70 percent of the time. The throttle flaps open and close about 100 times per lap. During a fast lap, such as 1:35 minutes, they change position about every 0.9 seconds.

Nico Müller's resume includes a victory in Monaco, a victory in Budapest and a 5th place finish in the Formula Renault 3.5.

The RE 35 DC motor is fitted custom quiver brushes, a special epoxy resin and a reinforced commutation system. All motors in the RE series have an ironless rotor and high-power permanent magnets (rare earth). They achieve more than 90% efficiency. To provide more torque for controlling the throttle of the Zytek V8 engine, the RE 35 is fitted with a GP 32 high-power planetary gearhead featuring an optimized output shaft. Depending on the reduction ratio, it can deliver up to 12 Nm.

The Maxon RE 35 has an ironless rotor and high-power permanent magnets suitable for the efficiency gains needed in racing.

Reliable under extreme conditions

The challenging application conditions — strong vibration and temps reaching up to 130 degrees Celsius — made special adaptations on the motor and gearbox necessary. John Manchester, Zytek operations director: "The support from Maxon motor during the test and evaluation phase has ensured that the motor is working flawlessly and reliably even in difficult conditions."

In the past, Draco Racing had pilots like Felipe Massa, Pastor Maldonado and Rubens Barrichello under contract. In other teams, the Formula Renault 3.5 has brought forth drivers like Sebastian Vettel, Fernando Alonso, and Robert Kubica. Vettel is a four-time Formula 1 world champion, Alonso has won the title twice. Muller's own resume includes a victory in Monaco, a victory in Budapest and a 5th place finish in the Formula Renault 3.5. His 2013 statistics have earned him a promotion. In 2014, he now spends the racing season as a factory driver for the Audi team in the famous Deutsche Tourenwagen Masters (DTM), trading in his Formula Race Car for one with a roof.

It's time to go home. Müller, dressed in denims and a polo shirt waves goodbye to the team before turning to the reporter: "The only times when you really control a race car is at full throttle and when braking." While the reporter is still thinking about what he just heard, Müller opens the trunk of his rental car, drops in his XXL training bag and gets behind the wheel to drive back to the hotel. His driving is slow, almost conspicuously unobtrusive. **PTE**

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The Automated Parking Garage

ContiTech and Wöhr Team up for Unique Residential Solution

The Hamilton Scotts Apartments are one of the best residential addresses the city-state of Singapore has to offer. The 30-story condominium offers a very special feature: Residents can park their luxury cars directly in front of their apartment. This is enabled by a fully automated parking lift sytem of Wöhr, which employs ContiTech timing belts.

Those with money in Singapore like to show it, for example with luxury cars and exclusive homes. For residents of the Hamilton Scotts Apartments, these two things lie close to each other: they do not park in front of the building or in a garage, but take their vehicles to the floor they live. Through a large glass pane, they can marvel at their vehicles in the "Sky Garage" from their sofa, while at the same time, they can let their eyes wander over the Asian metropolis.

For the project in Singapore, Wohr ordered 6,600 feet of the timing belt Conti Synchrodrive (photos courtesy of ContiTech).

While the residents reach their apartments by a passenger elevator, the parking lift takes their cars over at an access point at the ground floor in order to carry and park them in front of the particular apartment. This solution is not only exclusive, it also offers excellent space efficiency: "While underground parking requires extensive ramps and driving lanes, the parking lift system uses the existing space in the manner of a high bay," says Andreas Zangerle, development manager of Wöhr.

Extra-long belts

The belts that lift the vehicles up to a height of 370 feet come from ContiTech. "For very high parking lifts, timing belts are our first choice," says Zangerle. For the first time, they were used in 2006 for the parking systems in two 170 feet high towers in Mumbai, India.

For the project in Singapore, Wöhr has ordered 6,600 feet of the timing belt Conti Synchrodrive, in single lengths around 400 feet. "It is actually a standard belt," says Thomas Winkler, application engineering at ContiTech Power Transmission Group. "But it has never been installed in such lengths before." Usually, the belt is used in industrial lifting applications, where differences between 30 to 100 feet must be bridged.

Large weights are not a problem for the Conti Synchrodrive – it features steel cord, the strongest tension member in the ContiTech belt portfolio. But the belt provides other important characteristics as well, which are important for the project:

Conti Synchrodrive timing belts transmit rotary motions with angular accuracy.

A noise-reducing cover fabric makes it anti-static. "This protects the control electronics of the parking lift and can prevent disturbances in its operation," says Winkler. In addition, the tension member has been optimized: it offers a very low elongation and an improved setting behavior, which is important for the length required in Singapore.

Smooth parking

The cars are lifted on parking pallets. "The quick-change pallet system allows very speedy access, so that parking and exiting functions takes place smoothly and fast," explains Zangerle. The car elevator lifts up to ten tons upward with a speed of 9 feet per second. The elevator platform measures approximately 20 by 20 feet, it is supported by two timing belts at each corner.

"Of course, a rope or chain drive would have been a cheaper solution for the parking lift," says Winkler. But that applies only to the purchase. Due to the much lower maintenance costs of the belt – for example, lubrication is unnecessary – and their longer lifespan, belts are the more effective solution . Also, the noise level is kept within narrow limits, so that residents are not disturbed. And the teeth of the belt prevent slippage, so that the parking

lift comes to stop where it is supposed to, without complex position control.

ContiTech and Wöhr have been working together successfully for a long time. "But this was our most spectacular project so far," says Winkler.

Wöhr is a manufacturer of car parking systems in Europe. For more than 50 years – since the number of cars began to grow rapidly – the company has designed and installed parking lifts. As a supplier of brake systems, systems and components for powertrains and chassis, instrumentation, infotainment solutions, vehicle electronics, tires and technical elastomers, Continental contributes to enhanced driving safety and global climate protection. Continental is also an expert partner in networked automobile communication. Continental currently employs around 182,000 people in 49 countries. **PTE**

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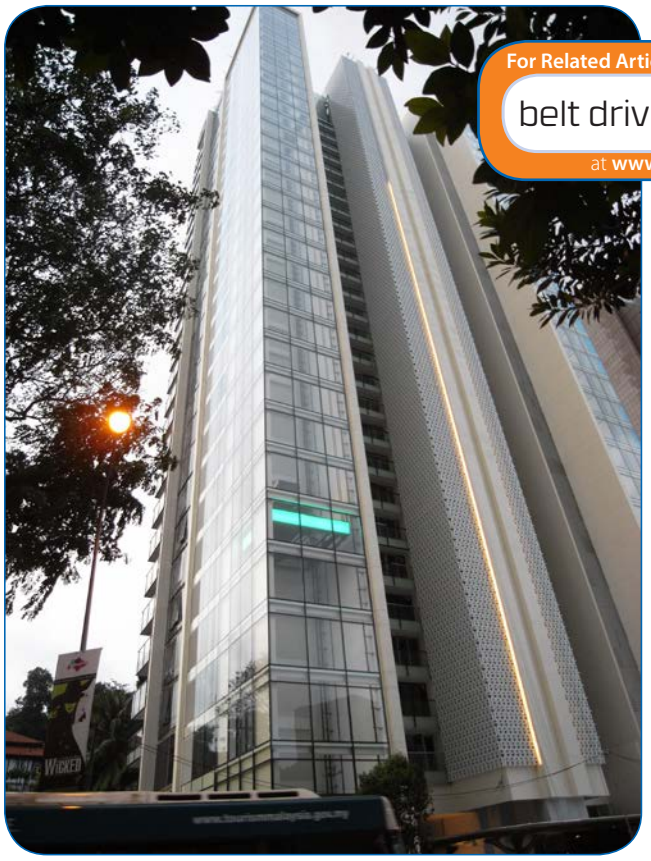

Hamilton Scotts Apartments in Singapore offers a unique parking solution that eliminates the space needed for an underground parking garage.

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Bosch Rexroth

Offers Hydraulic Solution for Blast Furnace

While the basic design of iron and coke blast furnaces is centuries old, today's steel makers are looking for innovative ways to produce molten iron with increased production and efficiency. That's why one of the world's largest steel producers in China turned to Woodings Industrial Corporation of Mars, PA (*www.woodingsindustrial.com*) to improve a key blast furnace component with a solution using Bosch Rexroth industrial hydraulics.

"The way iron pellets and coke are charged in layers inside a blast furnace really affects the melting process," says Al Colucci, Woodings Industrial, vice president, engineering "The layers are created by a system called a hydraulic distributor, using a chute located in the throat of the blast furnace, to deposit raw materials in precise locations."

"Woodings' challenge was to develop accurate control of the hydraulic distributor for a blast furnace, achieving a level of control previously unheard of in our industry."

Bosch Rexroth helped create a hydraulic circuit for Woodings' new hydraulic distributor for iron blast furnaces (all photos courtesy of Bosch Rexroth).

Handling the burden of the industry's tightest tolerances

A hydraulic distributor has two functions: rotating and tilting the chute. The more accurately the chute can be controlled, the more precise the layers and the more efficient the blast furnace becomes.

Woodings Industrial Corporation, founded in 1883, is a manufacturer of metals industry equipment such as tap hole drills, mud guns, blast furnace top hydraulic charging units, blast furnace valves and engineered specialty products.

One of its key customers, a major Chinese iron and steel producer, asked the team at Woodings to design and build hydraulically-controlled distributors for two new, 4,150 cubic meter blast furnaces that will produce up to 16 million metric tons of iron per year.

The majority of burden distributors use electromechanical gearing systems to drive the up-down movement of the distributor chutes. These systems do not provide the level of precision or control the Chinese steel manufacturer sought; in addition, they are difficult to repair and maintain in the high-temperature environments atop the blast furnace.

According to Woodings, the Chinese steel manufacturer had been using a hydraulic distributor of their own design on six blast furnaces. However, these systems used a traditional hydraulic circuit with open loop control. The end-user called on Woodings to help increase accuracy and performance.

The level of precision and control the company wanted was unprecedented for this type of system, according to Colucci They wanted chute movement at the endpoint limited to no more than 0.01 of an inch (0.25 mm). That's one-tenth of one degree."

Typically, burden distributor chute endpoint control is lower accuracy — within inches. However, Woodings' customer set this accuracy goal because they are convinced that the more precisely they can control the material distribution into the blast furnace, the more efficient and productive the blast furnace will be.

That degree of chute control is difficult to achieve, because as tons of iron ore pellets and coke tumble down the chute, the load and the angle of the chute change. The chute tends to extend when loaded, and when the load is released, it retracts.

Plus, all this is happening on the move. The chute rotates at 8 rpm, completing a cycle every 7.5 seconds. The rotation changes the loading on each of four hydraulic cylinders. The load on the first cylinder passes to the second cylinder, then to the third and fourth, then back to the first.

Adding to the challenge is the extremely demanding environment atop the blast furnace: with heat from the furnace, along with high levels of debris and soot associated with iron manufacturing. Given these conditions, it was necessary to position the hydraulic control valves for the circuit in an enclosure away from the cylinders, resulting in long hydraulic lines.

This distributed design has advantages: the hydraulic valves and controlling electronics last longer and are easier to maintain away from the harsh furnace top environment, and the hydraulic distributor uses far fewer rotating components, so that the control components last much longer.

However, the design presents a controls challenge: fluid in long hydraulic lines acts like a spring – expanding and contracting--making accurate motion control even more difficult.

Advanced simulation of dynamic loads

Woodings has had a working relationship with Bosch Rexroth since the 1990's. This application, however, was one of the most daunting drive and control challenges Woodings had ever presented.

"What made this project unique was the stringent specification on accuracy for an application with huge dynamic load changes," says Charles Erdo, Bosch Rexroth, industrial machinery engineer based in Bethlehem, PA. "The control system has to react fast enough to maintain a very tight cylinder stroke tolerance between four differential hydraulic cylinders."

The Woodings hydraulic distributor employs hydraulic cylinders with a controlled by 4WRPEH, directly operated high-response proportional directional valves, with electrical position feedback. The closed-loop cylinder-position control system utilizes load pressure feedback provided by HEDE 10 electronic pressure transducers.

To verify that the targeted accuracy and repeatability of the Rexroth hydraulics system would be achieved, Erdo involved Bosch Rexroth simulation groups in the U.S. and its headquarters in Lohr am Main, Germany.

"The short nine-month time window ruled out building a physical prototype to prove it to Woodings," Erdo said. "So we used several simulation tools to model the system."

Bosch Rexroth has been a leader in designing and utilizing advanced software tools to simulate the performance and effectiveness of hydraulic systems and controls. Simulation can save both time and development costs, while providing more accurate answers about how a complex array of hydraulic components will perform, without going through the cost and effort of assembling and testing a physical prototype.

Bosch Rexroth's proprietary simulation tool called MOSIHS (Modular Simulation of Hydraulic System), allows the user to model and simulate overall hydraulic system. With a library of standard hydraulic components and Bosch Rexroth valves, the engineer can design a system of any size and complexity and determine how it will behave. Each component can be parameterized to match the design requirements. An extensive array of electronic control and mechanical components is available in MOSIHS to replicate real world applications.

As in the real world, mechanical structures -- in this case, the distributor equipment -- interact with the hydraulic drive. Sub-models of the hydraulic system, mechanical systems and controls can be coupled with each other and simulated together. This allows the designer to investigate dynamic behavior of the overall system, including resonance modes of hydraulic and mechanical systems and the interaction of the controller, actuators and mechanical structure.

The hydraulic circuit and controls for the distributor, designed by Rexroth, comprised input data for the MOSIHS simulation program .CAD drawings of the distributor assembly, including 3-D models of Woodings-sourced components such as the chute and the rotating distributor head, were imported into a commercially available Multi-Body Simulation Program coupled with MOSIHS.

"It's unique for a drive and control company to have a dedicated simulation group developing software and libraries of model components, both hydraulic and electro-mechanical," Erdo said. "It gave us a real advantage in this application."

As the chute rotates through 360°, the chute is lifted and lowered by the Rexroth hydraulics to precise endpoints, as tons of iron ore and coke pellets pour down the chute into the molten iron in the furnace.

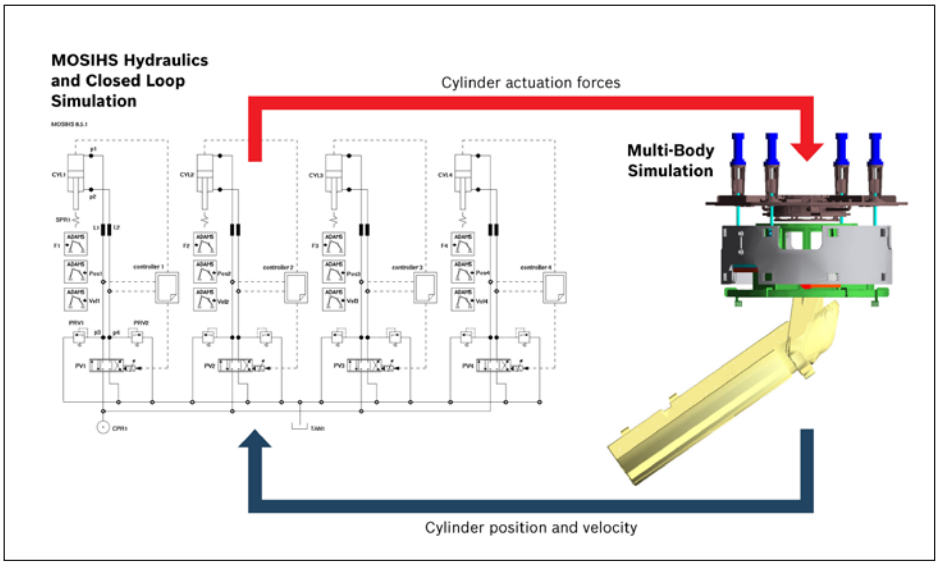

Figure 1 Simulation model of the distributor hydraulic circuit showing closed loop cylinder actuation forces and position and velocity.

The simulations verified the hydraulic circuit design and the selected Rexroth components were suitable to meet flow, pressure and other specifications, and demonstrated the required static, dynamic and response time behavior to reliably deliver the hydraulic distributor endpoint accuracy.

In addition, the MOSIHS simulation showed that using a specialized spool flow characteristic control valve would increase control performance. According to Erdo, this was a valuable improvement to the Rexroth hydraulic design, and one that would have been more difficult and time-consuming to discover using a physical prototype.

Virtual commissioning and 3-D animation help to convince customers

One of the most significant issues studied using the simulation was evaluating the hydraulic circuit's motion control scheme. Simulation demonstrated that a large moved mass and long hydraulic lines result in relatively low natural frequency of the hydraulic distributor system. Specialized control algorithms, using dynamic pressure feedback, actively damp system oscillations and provide optimal performance.

In the course of evaluating the closed-loop control and fine-tuning the system feedbacks, the Rexroth engineers developed a better understanding of how the forces moving through the chute can affect accuracy as the distributor rotated.

"As it turns out, the cylinder load changes with the chute angle" Erdo notes. "The drive and controls have to quickly react to load variations as the chute working point changes, as well as centrifugal forces and dynamic loads. The simulation verified our closed loop control strategy and demonstrated that all four cylinders remained synchronized as required."

The simulation also provided Woodings with an additional valuable tool: An animation which was used to prove to the Chinese steel manufacturer that the hydraulics solution Woodings proposed delivered their targeted endpoint accuracy. "That's good from the marketing perspective," says Erdo. "From an engineering point of view, it was reassuring to see all the components performed as specified."

Controls enable pinpoint accuracy

The hydraulic distributor control system utilizes advanced digital controls technology. A programmable logic controller (PLC) at the top level manages the closed loop control of the chute hydraulics and supervisory tasks; a variable frequency drive (VFD) handles the chute rotation; and a human machine interface (HMI) takes care of the front end for operator control and supervision.

The closed loop control of the chute angle is accomplished using position feedbacks located inside each of the hydraulic cylinders. The chute angle command comes from the blast furnace's upper level control system; this command is then converted to a cylinder position which is maintained by the controls. The PLC also controls

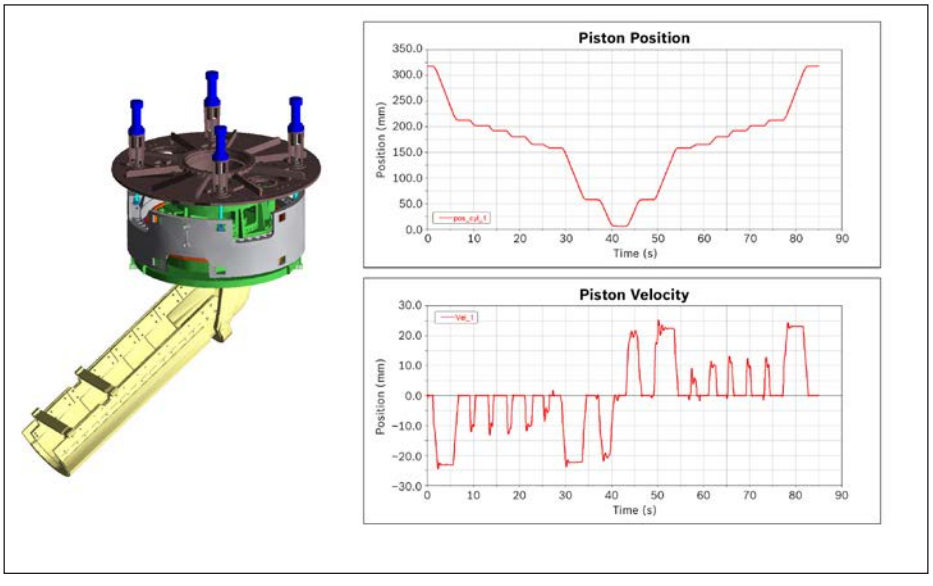

Figure 2 MOSIHS charts depicting the piston position versus piston velocity during 90-second distributor duty cycle.

ancillary functions such as burden distributor cooling, generating system alarms to be displayed on the HMI, and communicating with the steel mill's upper level control system.

Advanced components and engineering deliver accuracy

Along with performance challenges, Bosch Rexroth had a short delivery window for all of the components. Valves were obtained through Bosch Rexroth's *GoTo* focused delivery program for hydraulics, another service that gave Woodings a high degree of comfort with the Rexroth process.

Three final versions of the Woodings hydraulic distributor were assembled and tested at the company's facility in Youngstown, OH, to confirm proper function, after which they were then disassembled and shipped to China for installation. In addition, Woodings believes there is significant opportunity to introduce this hydraulic distributor technology to blast furnace operators worldwide, providing them with a system that offers dramatic improvements in distributor accuracy and repeatability.

"Bosch Rexroth made the deliveries they promised," Colucci says. "When we had inevitable situations where things didn't work exactly as expected, they stuck with me through the whole thing and came up with solutions. That's where this simulation was valuable. When we put the system on the test stand, it performed exactly the way we wanted it to go."

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TLC Still Needed For New Axles?

THE QUESTION

I have heard that new axles no longer need a break-in period. True or False?

Expert answer provided by Norm Parker, General Motors

The short answer to this question is a resounding, "false." But there is confusing information flying around that may be the source of these rumors. Let's start with the high-level goal of breaking-in or wearing-in an axle. There are two big wear mechanisms in an axle — the ring and pinion gear mesh (or hypoid mesh) and the bearings. There is some wear that occurs in the differential gears, but due to the intermittent usage, it is very slow by comparison. Providing the system is functioning correctly, most of the wear occurring in an axle will happen within the first 500 miles and then slowing down until around 2,000 miles where it eventually tapers off to into steady state. The overarching goal of the break-in period is to have the same functional axle that you started with.

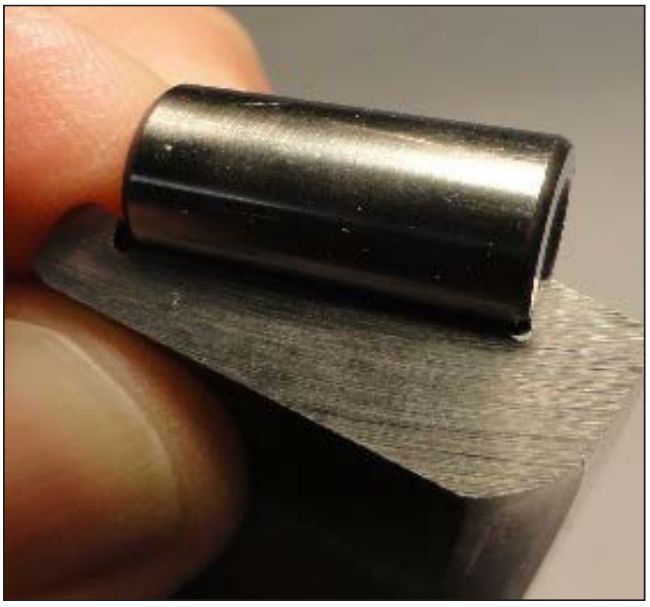
The bearing wear mechanism is fairly straightforward. All of the tapered roller bearings in an axle will wear to some extent between the bottoms of the rollers and the large rib that supports the heavy axial (horizontal) loads. Up until a few years ago, this surface started life around 2-3 µm Ra (~ 100µ in.). Over the course of a couple of thousand miles, this would smooth out to about 0.15 µm. During this period there was higher friction, which means higher heat and debris particles in the oil. Today, nearly all modern bearing companies provide honed ribs to the OEs, which are nearly standard product now. These are often marketed as 'non-wearing' or 'no-break-in' bearings. The honed rib surface is 0.1- 0.2 µm Ra, which greatly reduces the initial break-in wear (although it's not zero, as was the original intent). Honing takes care of surface finish but does not take care of part-to-part variation. There will always be a less-than-perfect fit between a new roller and a new rib. These parts must wear in *together* to achieve the perfect fit. We have found that no matter how smooth the mating parts are, there is still wear due to mating part tolerances. *Just a note of caution for rebuilt or repaired axles*: There are many aftermarket suppliers that will use cheaper bearings without honed ribs or, in some cases, have old inventory with non-honed ribs. Without having any sure way of knowing, you should err on the side of caution and assume that a rebuilt axle, or bearings ordered for a rebuild, do not have honed ribs.

The hypoid mesh is the other source of considerable wear and heat during the break-in period. Just as with the bearings, we are dealing with a surface finish that has to be polished down along with the mating gear teeth that need to run together for a period of time before there is true full contact. Unlike the bearing, there is both rolling and sliding friction in the hypoid. From a physical perspective this means that we can shear some of the surface finish off while some material can be rolled back onto the surface. You can loosely correlate this into elastic vs. plastic deformation of the local surface asperities. Higher force and lower lubrication film will force more shearing, while lower loads and a thicker film will allow more rolling. With rolling comes some surface work hardening which further adds to our benefit.

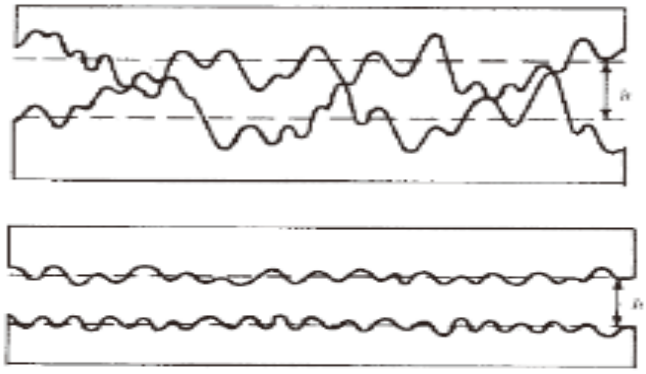
In order to help with the break-in period of the hypoid, most axles have some level of manganese phosphate coating applied to the ring and/or pinion. This is a chemically applied, hard porous coating that is intended to wear off during the first two thousand miles or so. There are a couple of benefits; the porosity allows the surface to hold more oil than a bare steel surface, which helps with lubrication during the higher-friction break-in period. Secondly, as the hard coating wears down, the surface asperities

and imperfections of the underlying gear are slowly introduced into the system, allowing the wear to occur much more slowly than two hardened steel parts mating for the first time. Phosphate coating isn't terribly expensive, but it isn't free either, so companies like to experiment with only applying phosphate to one surface vs. both. There is no industry-wide consensus on a best practice.

Similar to bearing superfinishing or honing, gear manufacturers use a process referred to as isotropic super-finish (ISF). This is exactly what it sounds like — non-directional honing. The principal behind the benefit is just the same as with the bearings. The traditional gear finish around 0.40 µm Ra with ISF can be reduced to 0.05 µm Ra. This results in much lower friction during the break-in period which produces less wear particulate running through the oil. This benefits all of the other components in the system as well. ISF is mostly used in aerospace at the current time, but is starting to gain momentum in the automotive industry as efficiency and performance demands continue to increase. This process certainly shortens the break-in period, but does not eliminate it.



TRB cross-section highlighting rib/roller interface.



New bearing vs. broken-in bearing.

The picture may start to become clearer as to why most current service manuals still recommend a 500 mile break-in period with no towing, hard acceleration or continuous driving. Even though honed surfaces can help with break-in, wear still occurs due to the imperfections of the mating parts. With all of the new surfaces coming together for the first time, a tremendous amount of wear occurs early in the life of the axle that creates heat. Heat reduces the viscosity of the oil which reduces oil film which further accelerates more wear and heat.

For these reasons, it is recommended to only drive a new axle for 15-20 minutes at a time before allowing it to cool down. Some manuals recommend not driving at highway speeds during the break-in to further protect the axle. For towing applications, it is also recommended to change the original axle oil after 500 – 2,000 miles to remove all of the wear particles generated during the break-in period. There is some question on the practicality of all of the break-in guidelines, but the error is on the side of caution; allowing for the worst case builds in the worst environments.

The long-term goal is to develop perfectly efficient axles that do not need a break-in period and never need the fluid changed. We are on our way there with honing, superfinishing and coating technologies, but in the meantime, take it easy on your new axle and you will be much happier with your long-term towing performance. **PTE**

Norm Parker is a General Motors technical specialist — driveline bearings/ Milford Proving Grounds, and a regular contributor to *Power Transmission Engineering* magazine.

Evolution of Worm Gear Standards and their Consequences on Load Capacity Calculation Approach

Dr. Michel Octrue

Beginning with a brief summary and update of the latest advances in the calculation methods for worm gears, the author then presents the detailed approach to worm gear geometry found in the revised ISO TR 10828. With that information, and by presenting examples, these new methods are explained, as are their possibilities for addressing the geometrical particularities of worm gears and their impact upon the behavior and load capacity of a gearset under working conditions based on ISO TR 14521 — Methods B and C. The author also highlights the new possibilities offered on that basis for the further evolution of load capacity calculation of a worm gearset based on load and contact pressure distribution.

Introduction

The geometry of worm gears has been developed over many years by internal convention specific to gear manufacturers, and by various authors who have contributed reference books on the topic (Refs. 1–6), but there has not always been consensus among them regarding definitions/terminology. There was a need for homogeneity and the first step in that direction was standard DIN 3975 — published in 1960. To further contribute to a better approach in the prediction of behavior of worm gears in first service, standardized methods have been published concurrently with geometrical definitions included in the same document as the load capacity calculation document (Ref. 7).

At the international level, the Working Group 7 of Sub-Committee One of ISO Technical

Committee 60 in charge of worm gears (ISO TC60/SC1/WG7) began work on this topic in 1992.

Development of the First ISO Technical Report on Worm Gear Geometry

The development of the unification of geometrical symbols of worm gears, and the associated calculation, began in 1992 in conjunction with the discussions over the concept of the load capacity of worm gears. It has since been decided to first develop a document with definitions of the different profiles of cylindrical worm gears that serves as the basis of the next step in creating the load capacity ISO documents.

The Technical Report ISO TR 10828/ Worm Profiles Geometry was published in 1997. The main target was to describe and provide the basic equations of the axial profiles of the thread profiles for the five most common types of worms (Fig. 1):

Type A: Straight-sided axial profile

Type C: Concave axial profile formed by machining with a convex circular profile disc-type cutter or grinding wheel

Type I: Involute helicoid, straight generatrix in base tangent planes

Type N: Straight profiles in normal plane of thread space helix

Type K: Milled helicoid generated by bi-conical grinding wheel or milling cutter, convex profiles in axial planes

From the axial profile, its projection in different plane was also defined in this TR in order to be able to determine (Fig. 2):

- The normal profile, to determine the shape of the flying cutting tool for machining the worm wheel
- The rack profile in offset planes used to calculate the conjugate worm wheel profiles
- The transverse profile of the worm which can be used for the control

(The decision of the WG to not include in this document all the geometrical definitions of worm gears is because similar work on a load capacity calculation standard is in progress, including the minimum set of geometrical relations requested by this second document.)

Evolution of Load Capacity Calculation Methods for Worm Gears

Due to the complex geometry, the load capacity of worm gears has been developed over a long period on standards based on industrial experience with empirical factors with two main criteria: contact pressure (some time called wear) and bending of threads.

Analytical methods, including geometrical aspects, have been developed with the power of computers, and the first version of DIN 3996 was published in 1998.

ISO TC60/SC1/WG7 developed and published the ISO TR 14521 — Calculation of Load Capacity of Worm Gears — in 2010; this standard is based on DIN 3996. The following conditions that can limit the rated load capacity are:

- **Wear**: such damage usually appears on the tooth flanks of bronze worm wheels
- **Pitting**: this form of damage may appear on the flanks of worm wheel teeth. Its development is strongly influenced by the load

This paper was first presented at the 2013 VDI International Conference on Gears, Technical University of Munich, Garching, Germany, and is reprinted here with VDI permission.

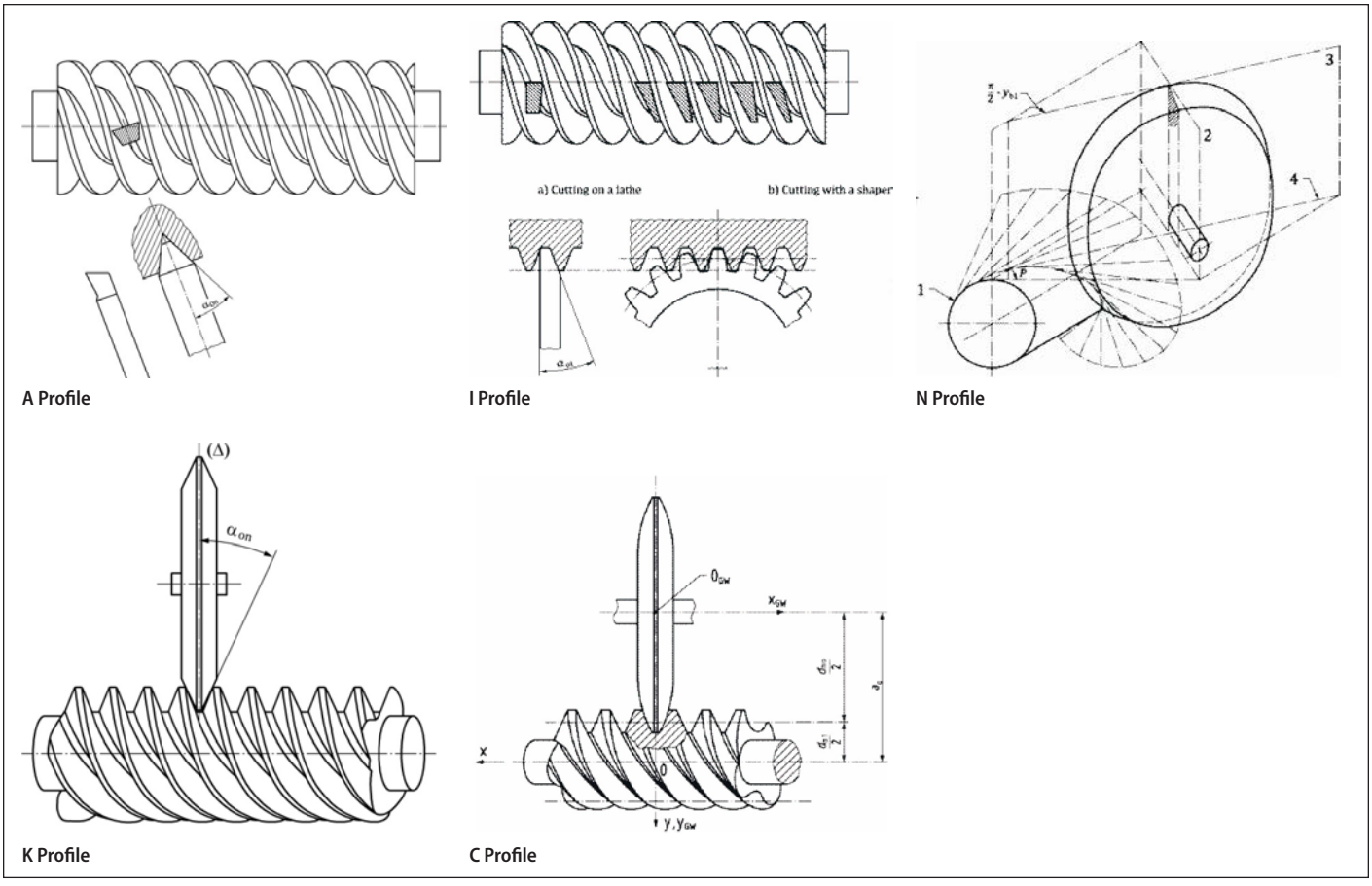


Figure 1 Cylindrical worm gear profiles.

transmitted and the load-sharing conditions.

- **Tooth breakage**: shear failure of worm wheel teeth or worm threads can occur when teeth become thin due to wear or overload.
- **Worm thread and worm shaft breakage**: shaft breakage can occur as a result of bending fatigue or overload.
- **Worm shaft deflection**: excessive deformation under load modifying contact pattern between worm and worm wheel.
- **Scuffing**: this form of damage often appears suddenly and is strongly influenced by transmitted load, sliding velocities and the conditions of lubrication
- **Working temperature**: when excessively high working temperature leads to accelerated degradation of the worm gear lubricant.

The calculation of load capacity is based on the following criteria, which are linked as follows:

- Criteria for pitting and criteria for worm shaft deflection are independent of others
- Criteria for wear and criteria for tooth breakage of worm wheel are dependent because the reduction of worm wheel tooth thickness by wear is taken into account for the calculation of shear stress at tooth root

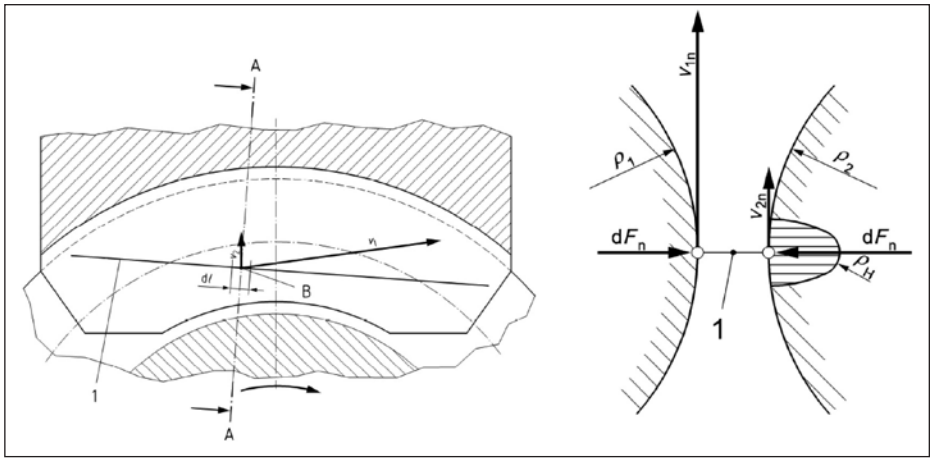


Figure 2 Contact line on a worm wheel and Section A-A normal to the contact line 1.

Criteria for wear is function of oil film thickness, which depends on oil film temperature, so the calculation of different type of power losses in order to determine the wheel bulk temperature, is the first step for wear calculation

In order to isolate the influence of geometry on the zone of contact and the lines of contact, it has been defined non-dimensional parameters:

p_m^* = mean Hertzian stress
h^* = mean lubricant film thickness
s^* = mean slip path.

To determine those non-dimensional parameters TR 14521 defines two methods:

Method C: Based on simplified formulae which are given in the TR and which are available in a cer-

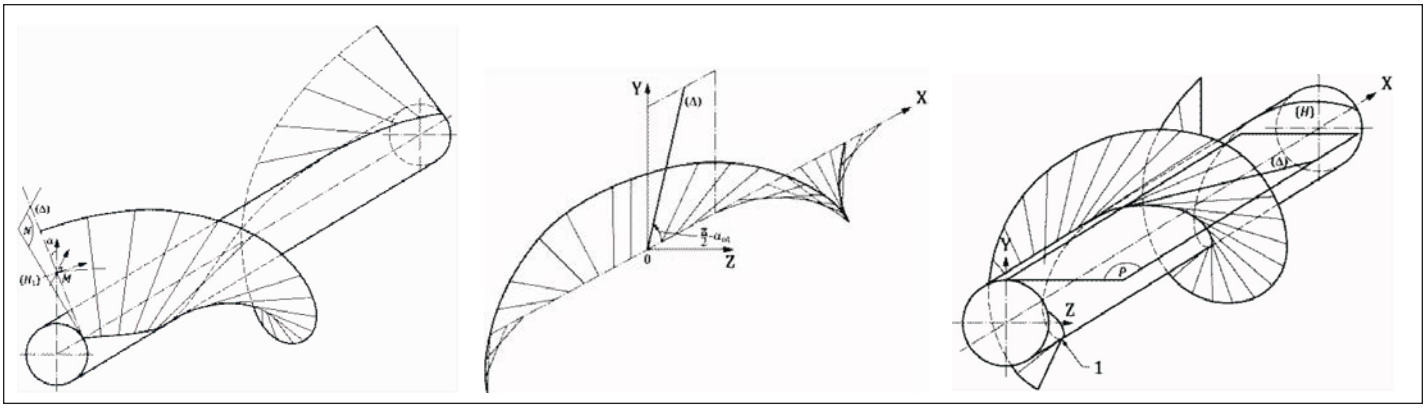


Figure 3 A, I and N profiles generated by a helical cylindrical displacement of a straight line.

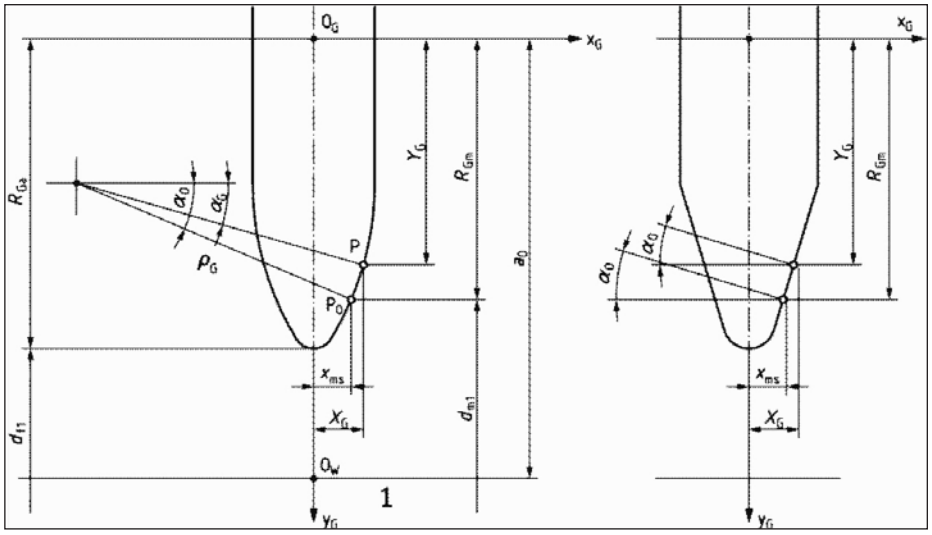


Figure 4 C and K profiles grinding wheel parameters.

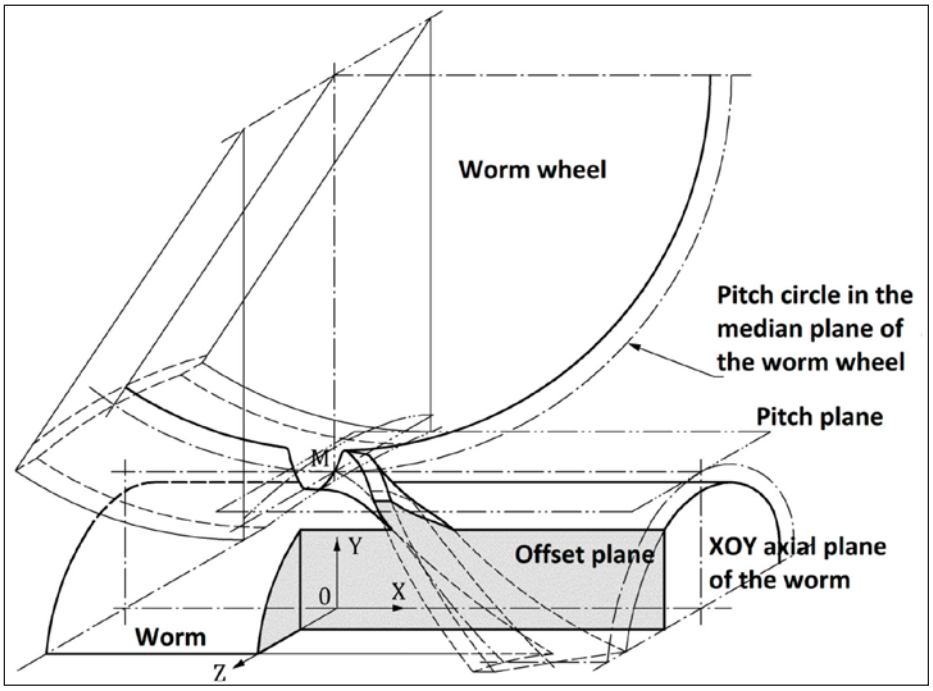


Figure 5 Pitch surfaces and offset plane.

tain range of basic geometrical parameter range: the equations apply to flank form I but can also be used in an approximate manner for tooth forms K, A and N. The approximation formulae for C-worm drives are derived from Bibliography (25) and from operational experience. The approximation equations indicated in 7.3.1, 7.3.2 and 7.3.3 apply to I-worm drives with $\alpha_n = 18...\ 22°$, $x_2 = -0.5...\ +1$, $h_{am1} + h_{am2} \approx 2 \cdot m_{x1}$, C-worm drives with $\alpha_n = 20...\ 24°$, $x_2 = 0...\ +0.5$, $h_{am1} + h_{am2} \approx 2 \cdot m_{x1}$ and $\rho / m_n \approx 5...\ 7$.

Method B: based on numerical determination with a detailed study in each point of the lines of contact in terms of radius of curvature, sum sliding velocity in the normal direction, and mean local sliding path (Fig. 2).

How to Define a Standard for Geometry of a Worm Gear

Taking into account the complex geometry of worm gearing, and in order to apply Method B for all types of worm profiles, it was important to clarify the application of Method B and to enlarge the scope of TR 10828 to the definition of a complete standard on the geometry of worm gear.

Method B must also be used because the use of geometrical parameters like normal pressure angle, addendum coefficient, face width and external diameter for worm wheel evolve in a significant range from one gear manufacturer to another, and are not sufficiently explained in Method C.

So the revision of ISO 10828 was launched at the end of 2010 with a new

tittle — "Worm Profiles and Gear Mesh Geometry."

Content of Revised ISO 10828

First of all, the different geometrical parameters for the worm and the worm wheel, as well as for the pitch surfaces defined previously in the ISO/TR 14521, have been revised and included in the revision. The goal is to delete those definitions in the future revision of ISO/TR 14521 in order to have a unique definition.

The main improvement concerns the following points:

1. Worm profiles have been split into two families, and axial worm profiles have been defined:
   a. Profiles generated by a helical cylindrical displacement of a straight line that is available for A, I and N profiles (Fig. 3): For those three profiles a general equation has been set up; each profile is accessible by using the correct coefficients. The main parameter of those profiles is the radius in the axial profile of the worm.
   b. Equations for profiles generated by a profiled disk grinding wheel, as for K and C profiles (Fig. 4): Each profile is accessible by the equation of the grinding wheel profile. The main parameter of those profiles is the radius of the axial profile of the grinding wheel. There is not a direct relation to obtain the axial profile of the worm.
2. In order to define the conjugate profile of the worm — i.e. — the worm wheel profile, the path of contact and the lines of contact — the rack profile of the worm in an offset plane is determined from the axial profile. It means that the gear mesh of a worm gear set is studied in several offset planes parallel to the median plane of the worm wheel crossing the axis of the worm. It can be noticed that for the rack profile of the worm, the two flanks are never symmetrical. On one flank the pressure angle is increasing, while on the other the pressure is decreasing (Fig. 5).
3. With the definition of pitch surfaces:

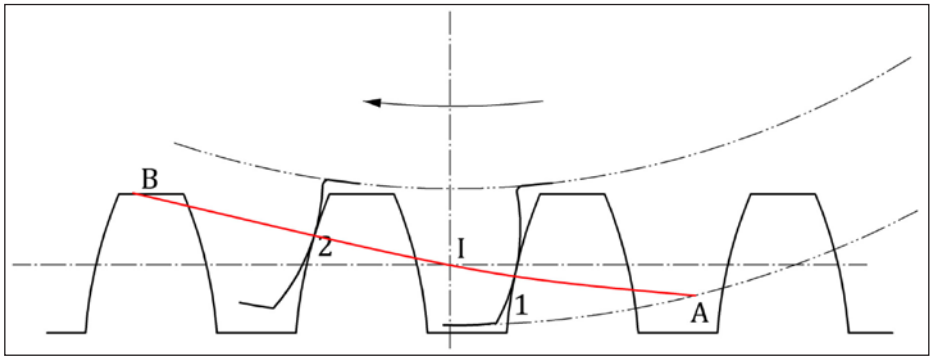


Figure 6 Active path of contact AB.

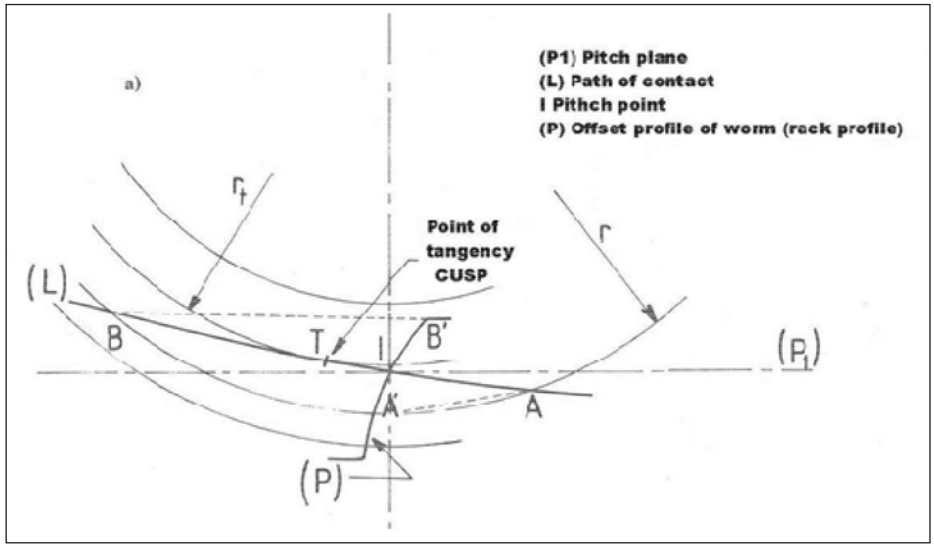


Figure 7 Cusp effect to limit path of contact to AT.

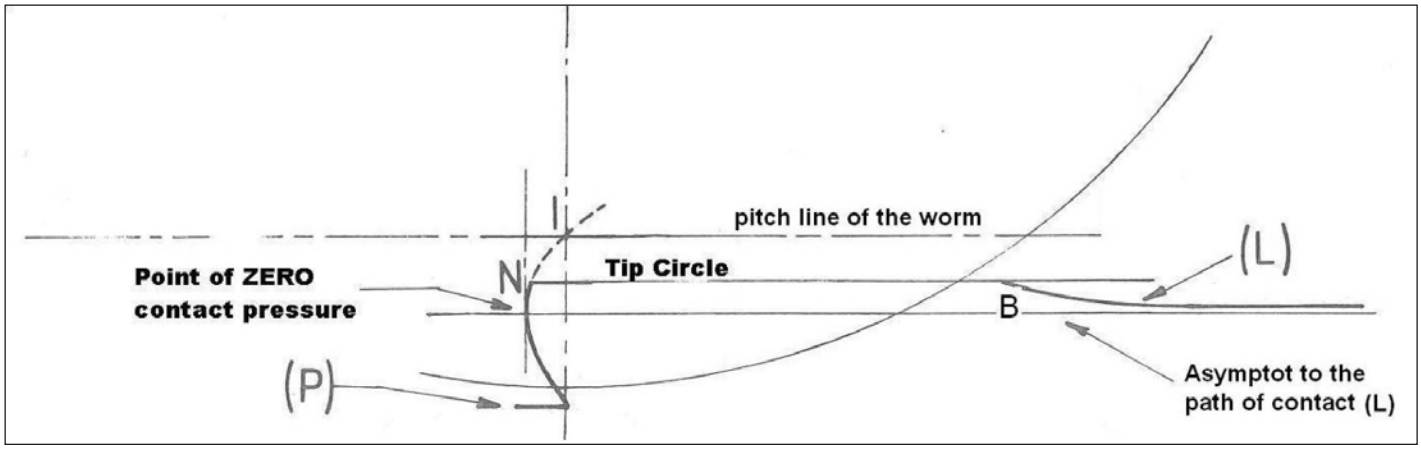


Figure 8 Limitation of gear mesh by the point of zero contact pressure angle.

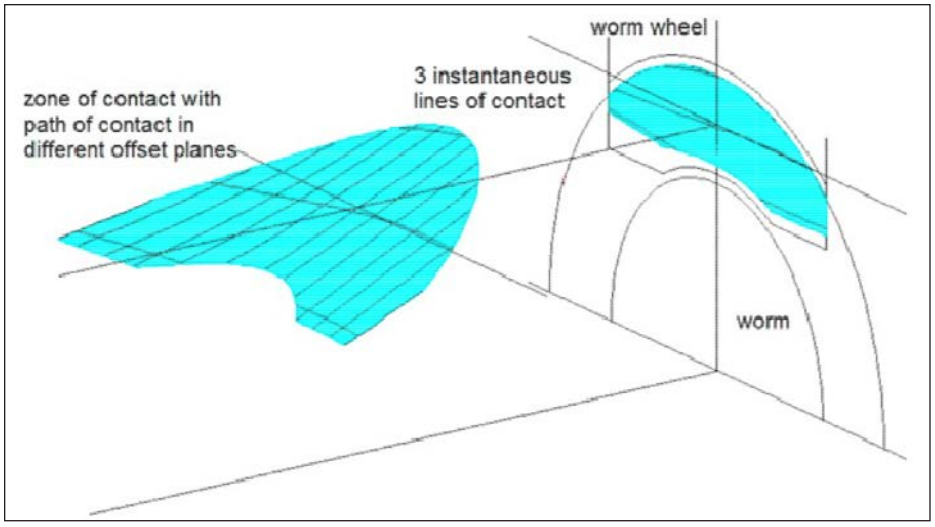


Figure 9 Path of contact, zone of contact and lines of contact for one relative position of worm and worm wheel.

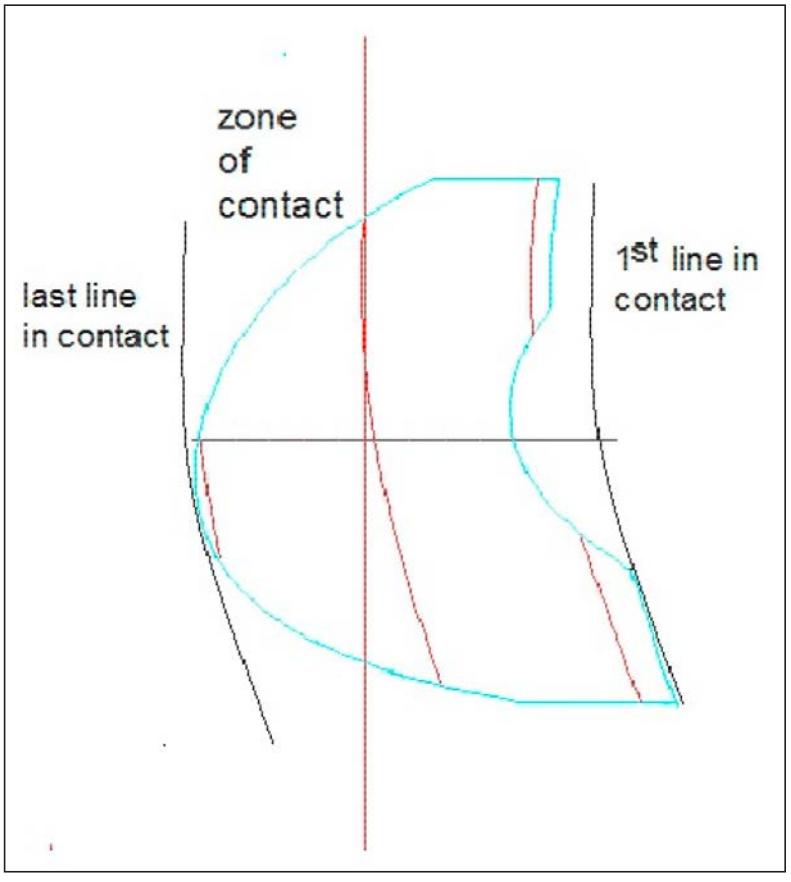


Figure 10 Contact ratio.

a. For the worm: A plane parallel to the axis of the worm and the axis of the wheel with distance to the axis of the worm equal to the half of pitch diameter d_{w2}
b. For the worm wheel the pitch cylinder is defined with the pitch diameter d_{w2}
c. The pitch cylinder of the wheel is rolling without sliding on the pitch lane of the worm. The common tangent between the two pitch surfaces is called pitch axis; it is also the instantaneous axis of rotation.

4. In each offset plane, the rack profile of the worm, projection of the axial profile of the worm, allows to define the path of contact, which is the line along which the common point of contact between the flank of the worm and the conjugate flank of the worm wheel is moving during the gear mesh. From this line can be obtained the profile of the worm wheel. The shape of the path of c ontact can be concave or convex it; depends directly on the curvature of the rack profile of the worm. The pressure angle can be lower than zero. The zero contact pressure angle is a characteristic of worm geometry (Fig. 8).
5. Then it is important to determine the limits of the active path of contact. In principle it is limited by the outside active cylinder of the worm and the external circle of the external surface of the worm wheel (Fig. 6).
6. In certain circumstances the active path of contact can be limited by artifacts in the gear mesh due to:
   a. Either by the presence of cusp (Fig. 7) when the path of contact is very flat when the pressure angle decrease and the contact exist only between A and T.
   b. Either there is no active path of contact (Fig. 8) when the pressure angle is closed to zero; B is outside of the external surface of the worm wheel.
7. Before to determine the line of contact between the flanks of the worm. It is important to determine in each offset plane the limits of active path of contact as described in points 5 – 6. This defines the zone of contact. Then for each relative position of the worm

example number	1	2	3	4	5	6
Assumption: ha1*=ha2*=1 hf1*=hf2*=1.2 he2*=0.5						
Type of flank ZA ZK ZJ ZC ZJ ZC	ZA	ZK	ZI	ZC	ZI	ZC
number of threads z1	2	2	2	2	2	2
axial module mx1 mm	4	4	4	4	4	4
diameter factor q1 -	9	9	9	9	10.28	10.28
normal pressure angle αn °	20	20	20	20	20	20
reference lead angle of worm γm1 ° 12.53 11.01	12.5288077	12.5288077	12.5288077	12.5288077	11.0095079	11.0095079
worm reference diameter dm1 mm	36	36	36	36	41.12	41.12
worm root diameter df1 mm	26.4	26.4	26.4	26.4	31.52	31.52
worm tip diameter da1 mm	44	44	44	44	49.12	49.12
number of teeth z2	41	41	41	41	39	39
worm wheel profile shift coefficient x2	0	0	0	0	0.36	0.36
worm wheel reference diameter dm2 mm	164	164	164	164	158.88	158.88
worm wheel root diameter df2 mm	154.4	154.4	154.4	154.4	149.28	149.28
worm wheel tip diameter da2 mm	172	172	172	172	166.88	166.88
worm wheel outside diameter de2 mm	176	176	176	176	170.88	170.88
effective wheel facewidth b2H mm	30	30	30	30	30	30
wheel rim width b2R mm	30	30	30	30	30	30
outside diameter of the grinding disk dgr mm		309.6		309.6		309.6
profile radius of grinding disk ρ mm				24		24
centre distance a mm	100	100	100	100	100	100

type of flank	ZA	ZK	ZI	ZC	ZI	ZC
pm* Method B	0.8561	0.8687	0.8726	0.8536	0.8887	0.7377
pm* Method C	0.9496	0.9496	0.9496	0.7415	1.0797	0.8432
h* Method B	0.076	0.0745	0.0743	0.0855	0.079	0.0986
h* Method C	0.06891	0.06891	0.06891	0.08948	0.0658	0.0854
s* Method B	31.4293	30.8437	30.7635	33.8615	33.134	40.6564
s* Method C	30.285	30.285	30.285	36.215	33.659	40.253
Cusp in the gear mesh	**no**	**no**	**no**	**yes**	**no**	**yes**

Difference in % for pm*	-9.85%	-8.52%	-8.11%	15.12%	-17.69%	-12.51%
Difference in % for h*	10.29%	8.11%	7.82%	-4.45%	20.06%	15.46%
Difference in % for s*	3.78%	1.84%	1.58%	-6.50%	-1.56%	1.00%

and the worm wheel the lines of contact can be determined (Fig. 9).

8. The contact ratio of the worm gear can be determined by comparison of the position of the worm when the 1st line of contact is in contact with the beginning of the zone of contact and the position of the worm when the last line of contact is in contact with the end of the zone of contact (Fig. 10).
9. In each point of contact it is then possible to determine:
   a. From the geometry: the normal vector, the tangential plane, the main and equivalent radius of curvature
   b. From the kinematic conditions the rolling and sliding velocities
10. Revision of ISO/TR 10828 develops all the equations and algorithms to determine all the characteristics developed in points 1 – 9. For better understanding — and in order to be able to test algorithms — *MathCad* files have been developed in the framework of the ISO TC60/SC2/WG7.

Examples of the Application of Revised ISO 10828

The following table summarize different calculation examples run for a same set of data with different worm profiles A, I, N and C for a same reference lead angle for examples 1 through 4 and for another reference lead angle for examples 5 and 6:

It can be observed that ISO/TR 14521 Method B (based on Revised TR 10828) and Method C provide significant differences for the non-dimensional parameter p^*, s^* and h^* — which can justify the clarification brought by the Revised TR 10828 in the application of Method B by detailed complex geometry calculations.

In those calculations the face width of the worm wheel has been divided in 53 offset planes and 20 relative positions between worm and worm wheel have been studied.

For p^* and h^* Method C is on the conservative side (oversizing gear set) — but not for s^*. In the case of cusp (C Profile), Method C is not applicable.

To illustrate the impact of cusp, the details of Example 4 are presented in Figure 11. It can be observed that the reduction of the zone of contact (in particular, there is an area where the lines of contact do not reach the outside diameter of the worm). On the left, the gear mesh in the median plane of the worm wheel emphasizes the phenomena. The other consequence is that when cusps exist, the equivalent radius of curvature is close to zero for the points on the border of the zone of contact (Fig. 12). It means that it is recommended to avoid cusp in gear mesh by increasing normal pressure angle.

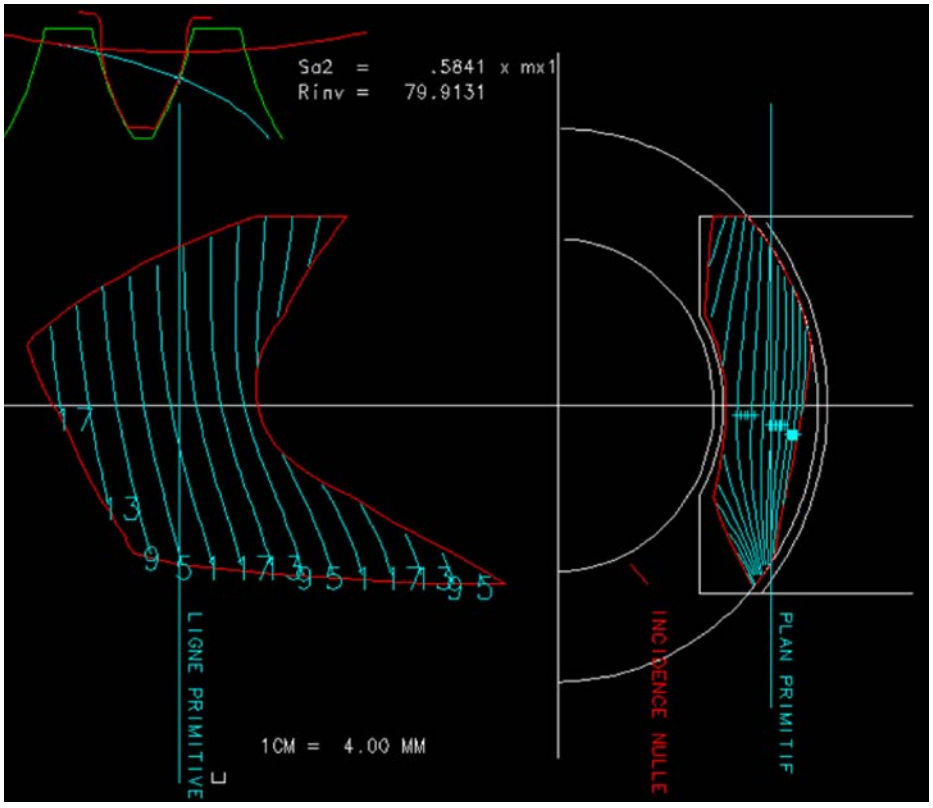


Figure 11 Example with cusp effect and reduction of zone of contact.

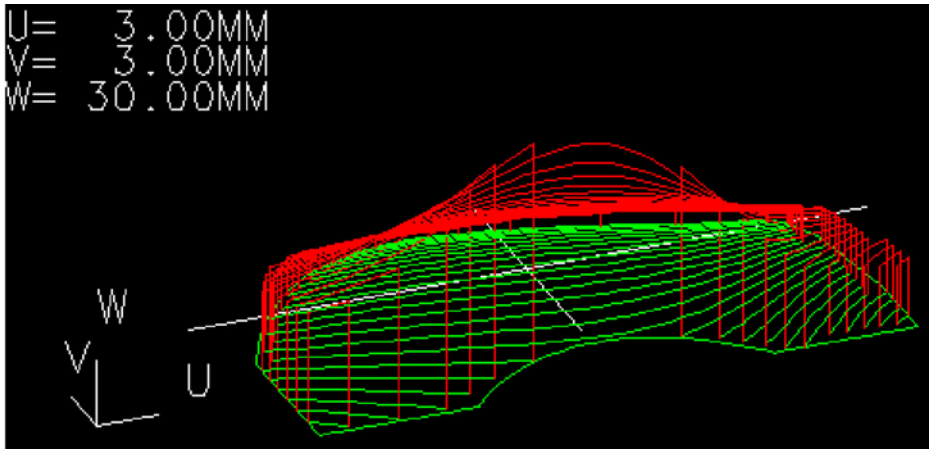


Figure 12 Equivalent radius of curvature in projection on worm wheel flank.

Dr. Michel Octrue is a CETIM (Centre Technique des Industries Mécaniques) expert in the field of mechanical power transmission as a specialist in the behavior of mechanical components (gears, roller bearings, etc.), with particular expertise in projects involving mechanical power transmission components and their integration in machinery and gearboxes for automotive and transportation devices. His experience covers the different stages — design and calculation; choice of tolerances; selection of materials and heat treatment; and development and validation by numerical simulation or testing devices. He is also involved in testing strategy and test bench design for mechanical components. Octrue is a graduate engineer from ECAM–Lyon, where he subsequently earned his doctorate in engineering. Among his technical achievements are the design and realization of software and training sessions to transfer the knowledge in the fields of gear technology (gear design, gear rating, gear tolerances and gear behavior in noise and vibration; the development of test benches for endurance to characterize cylindrical and worm gears; the design and realization of several test benches for gearboxes and different machine elements; the participation and animation of working groups in standardization activities in the framework of ISO TC60 – Gears; and the development of methodologies to reduce gear noise at the source. Octrue also serves as a technical expert for ANVAR, is speaker (20 int'l pubs), and has authored two books on worm gears (New Method for Designing Worm Gears and An Industrial Approach for Load Capacity Calculation of Worm Gears (Verifying and Design).

Possible Extensions Provided by Revised TR 10828

The geometry of worm gears can be extended for any type of grinding wheel disk profile; one simply introduces the mathematical function of that profile and all the theory is still available.

The other possible extension is for the future evolution of ISO/TR 14521, in which at the moment the contact pressure distribution is considered as a constant value. However this assumption is far from reality, and industrial results have shown that this was not correct.

This type of calculation (radius of curvature, normal vector, etc.) can be used also for other mechanical components — profiles for roller screws, for example.

Conclusions

- The complex geometry of worm gear is now clearly detailed and Method B of ISO/TR 14521 is more accessible.
- This Technical Report will bring a better knowledge and understanding of the behavior of worm gears for the future. **PTE**

Acknowledgement. *Thanks to all members of ISO TC60/SC1/WG7 for their active participation in the elaboration of these standards.*

References

1. H.Winter-Niemann, H. *Maschinenelemente,* Springer 1996.
2. Merritt Gears, 1946.
3. Buckingham, E. *Design of Worm and Spiral Gears,* Buckingham Associates Inc., 1960.
4. Henriot, G. *Traité T héorique et Pratique des Engrenages,* T1 et T2-Ed., Dunod 1979.
5. Octrue, M. "Géométrie des Roues et vis Tangentes," NT N° 22 CETIM 1982.
6. Octrue, M. "Complément de Géométrie et Méthodes de Contrôle dans les Roues et vis Tangentes," NT N°23 CETIM 1982.
7. BS 721 – 1963 -Confirmed 1984: *Specification for Worm Gearing.*
8. DIN 3996 -1996: *Calculation of Load Capacity of Cylindrical Worm Gear Pairs with 90° Shaft Angle.*
9. DIN 3975-1960 Standard: *Definition of Cylindrical Worm Gear Pairs with 90° Shaft Angle.*
10. AGMA Standard 6022-C93: *Design Manual for Cylindrical Worm Gearing.*
11. AGMA Standard 6034-B92: *Practice for Enclosed Cylindrical Worm Gear — Speed Reducers and Gear Motors.*

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Wind Turbine Field and Test Rig Testing as Part of the Design Process for Gearboxes: Test and Validation Requirements, Needs and Best Practices for Wind Turbine Gearboxes

Frank D. Krull

The growth of worldwide energy consumption and emerging industrial markets demands an increase of renewable energy shares. The price pressure coming from coal, oil, nuclear and natural gas energy — combined with enormous worldwide production capacities for components of wind turbines — make wind energy a highly competitive market. The testing and validation of gearboxes within the test rig and the turbine environment attract a strong focus to the needs of the industry. The following contribution sums up the typical process requirements and provides examples for successful system and component verifications based on field measurements.

Introduction

Wind turbines and their components are part of a dynamic environment; very often, hot and cold climates have profitable wind conditions that make those sites attractive for wind park projects. Components of turbines located in these extreme weather patterns are impacted by strong, gusty winds, deep temperatures, ice, snow and hot and humid climates. The load on components, combined with the tough environmental conditions, require robust requirements for the engineering of main and sub-systems, as well as their lubrication — most particularly the gearbox. A full understanding of the interaction between gearbox and wind turbine — with the different combinations of towers, rotor blades, generators, and resulting loads that are related to different site conditions — must be demonstrated by sound system engineering methods and their validation. Multi-body simulations, FE approaches of complete systems, and the validation on test rigs and on-site installations are all part of the gearbox development process. International Organization for Standardization Abstract IEC61400-4 states the recommendations for test criteria, sensors and sensor positions.

Test and sensor plans should be discussed between wind turbine manufacturer, gearbox manufacturer and component supplier, regarding lubrication and bearing supports.

Gearbox Simulation Models and Test Rig Environment

The gearbox is the most complex, dynamic sub-system within the mechanical drivetrain, which is why it is so important to create an accurate simulation model that is valid and suitable to mirror the major inner dynamics.

The test rig environment helps to validate the gearbox simulation models and to better understand the gearbox's specific dynamics. What's more, the complexity level of the test rig environment is simpler and better controlled than the on-site turbine environment; this allows planning test-run parameters based on first simulation results. Test rig simulation and measurement provide an opportunity to plot sensors for the validation measurement of the model under controlled and repeatable conditions, thereby closing the first development loops within the design phase and helping to save cost and reduce risk.

Within the first step it is necessary to keep the test rig model as simple as possible. The test rig is driven by a 5 MW motor and a slave gearbox; the slave gearbox with a shift stage adapts the torque and speed to the input level of the master gearbox. The generator is connected to the output shaft of the master gearbox via an original wind turbine coupling, including the brake disc. Original rubber bushings from the wind turbine isolate the gearbox torque arm from the foundational support structure. The mounting angle of the drivetrain corresponds to the original mounting angle of the wind turbine drivetrain.

The ground supports, gearbox housing, and planet carrier of the planetary stages are considered as elastic elements (FEA super elements/blue-colored). The technology for those considerations is based on a mode reduction of the finite element models. Periodic tooth stiffness achieves authentic model stimulations occurring with tooth mesh frequency; the sub-models account for the overlapping effects of real toothings. Accurate n-dimensional (*Ed.'s Note: having an arbitrary number of dimensions*) stiffness characteristics of the bearings include the information of the bearings' microgeometry. The displacement between outer ring and inner ring causes reaction forces on the shafts and housing. Forces and displacements of the shafts depend on the kind of bearing models used.

This paper was first presented at the 2013 VDI International Conference on Gears, Technical University of Munich, Garching, Germany, and is reprinted here with VDI permission.

Different accuracy levels of models for bearing stiffness can be used for parameter and sensitivity studies; bearing stiffness can be modeled with linear and/or non-linear properties.

The degrees of freedom (DOF) of real bearings are constrained by coupling stiffness. Thus the simulation results for bearing models with constrained DOF and non-constrained DOF will be different. The choice of a suitable bearing model depends on the simulation targets (e.g., calculation efficiency and/or result accuracy).

The support structure and complex structural parts of the drivetrain — such as parts of the crankshaft — are considered as super elements.

Excessive analyses and verifications of the gearbox within a test rig environment due to measurement and simulation are necessary for highly accurate validation of the gearbox model. And, the quality of the gearbox model has a huge impact on the quality of the simulation within the wind turbine model. Investigating model details on a high technological level is recommended in order to gain an accurate validation model for the gearbox. Closing engineering loops supported by multi-body simulation results will help to enhance the suitability of the gearbox design and its reliability for the application within a wind turbine.

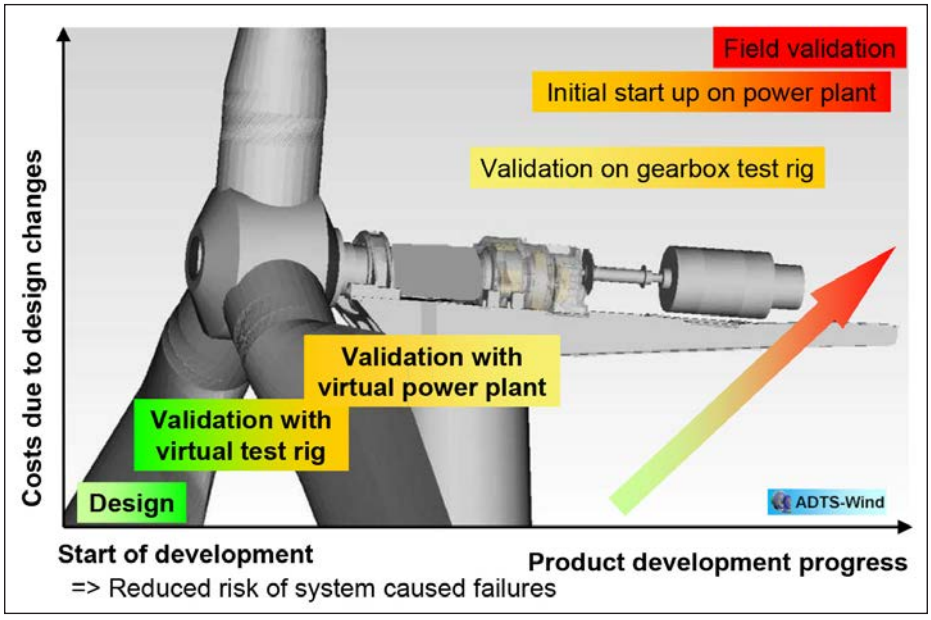

Figure 1 Early-stage validation of gearbox; note relationship between development phase and cost increasing due to necessary design changes of gearbox.

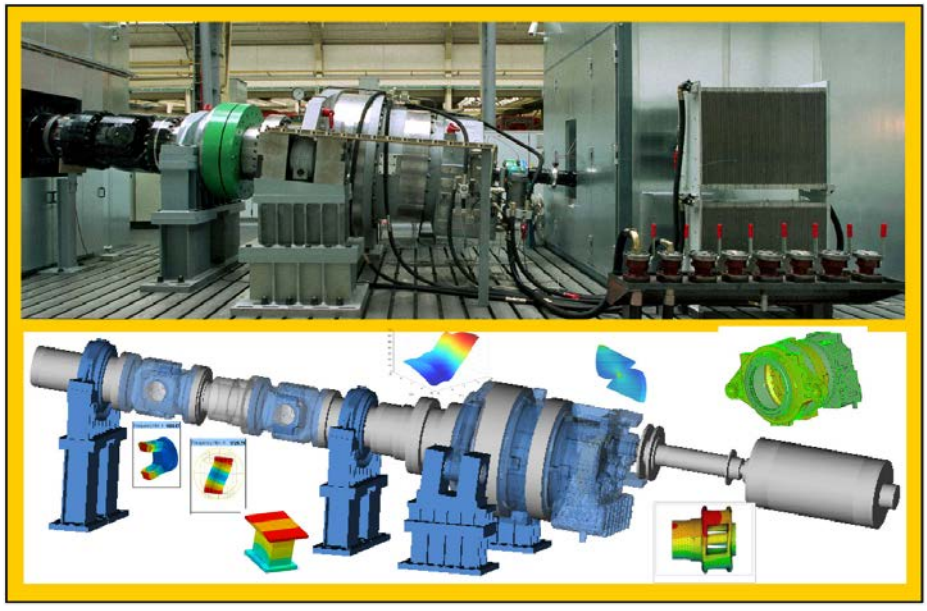

Figure 2 Photograph and simulation basis for 5 MW Wind turbine test rig; MBS (multi-body system) of the gearbox within the test rig environment.

Operating Conditions of Wind Turbines

Availability and production gains of wind turbines depend on various operating conditions; but loads and temperatures vary — depending on a turbine's condition speeds. A high amount of control activities under turbulent and strong wind conditions lead to non-stationary loads and speeds. The design and suitability of support systems, bearings and toothings — as well as lubrication — are relevant for reliable component lubrication.

Agreement between environmental conditions and functionality:

- Cold climate → maintaining the lubrication and filtration system; supply of the tribo-contacts; materials; fracture mechanical fatigue
- Frozen gearbox → capability to start the pressure-fed lubrication; avoiding of coal oil at heating elements; short starting periods; material; brittle crack propagation
- High speeds, low loads → avoiding smearing
- Low speed, high loads → avoiding micropitting and wear
- High speed, high loads → avoiding scuffing
- Stand still → Avoiding still-standing marks and "false brinelling"
- Idling → supply of toothings and bearings above the oil sump
- No grid → minimum supply of components during parking periods

There are a couple of other operating conditions that should be addressed by testing, calculation and simulation.

Tests and Test Criteria for Wind Turbine Gearboxes

Tests for wind turbine gearboxes as part of the design process are to be differentiated by eight different categories:

1. Prototype tests on a gearbox test rig
2. Robustness tests on a gearbox test rig
3. Cold climate tests in climate chamber
4. Component and sub-system tests (lubrication systems, etc.)

Figure 3 Eickhoff 5MW test rig with climate chamber.

Figure 4 Verification of the specific required oil quantities for toothings and bearings.

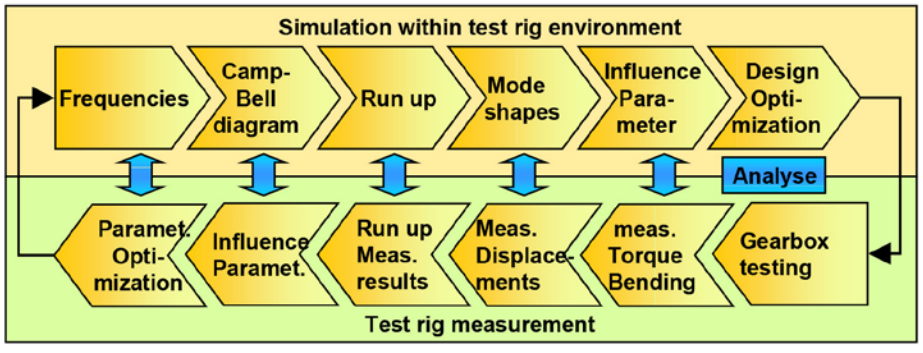

Figure 5 Coherences between influence parameters and design loop; analysis of test and simulation within optimization loop.

5. Material test (strength tests, quality tests, etc.)
6. Field tests of the gearbox
7. Field tests of the gearbox oil
8. Acceptance tests for series production on the test rig of the gearbox manufacturer

The prototype tests cover the confirmation of the main design assumptions; the functionality of parts; the fulfillment of noise and vibration criteria; and temperature limits and lubrication criteria.

The robustness test of a gearbox is related to its fatigue and should expose its weakest link. This test can be conducted as an accelerated fatigue and/or overload test.

Cold climate tests within a cold chamber confirm the functionality of the lubrication system under extreme low temperatures, and verify start-up and warm-up strategies of the gearbox up to the minimum operation temperature.

Component and sub-system tests confirm design assumptions and verify calculation results. Material tests qualify properties of brittle cast iron and temperature, depending on the properties of steels used for the toothings. Quality tests are necessary to assure the specified material properties with respect to chemical consistency, grain sizes and metal structure.

After the prototype test of the gearbox at the test rig, a prototype qualification and validation on-site is required. Design assumptions, load assumptions, deflections and deformations are measured and considered as the basis for lessons-learned loops during the design assessment. Field tests for lubricants qualify the lubricant with respect to compatibility with all components within the gearbox under field environment conditions. Those tests are, in addition to prequalification tests, application-oriented lubrication tests.

Series and acceptance tests are required as end-of-line tests for each gearbox that will be delivered to the customer. Those tests have to be operated with specified load steps up to nominal load under consideration of requirements to test criteria such as maximum temperatures, pressure lim-

its, noise and vibration limits and contact pattern at the toothings.

Test and Qualification of the Gearbox Lubrication System

The approval of the lubrication system is important for prototype and end-of-line testing. During prototype tests, the expected amount of oil, temperature, pressure and oil cleanliness must be confirmed. In addition, the suitability of emergency lubrication for idling and grid-less parking conditions of the wind turbine must also be proven.

During the acceptance tests of the gearboxes, the confirmation of expected temperatures and pressures assures the completeness and functionality of the oil pipes as well as the anti-leak tightness of the lubrication system.

This concept excludes damages due to lubrication faults and leakages. Prototype testing under CCV conditions — including the verification of lubrication design assumptions — is paramount; tests within a cold climate chamber ensure the suitability of design assumptions and operating strategies of the wind turbine.

Freezing the gearbox down to an extreme temperature of –40°C provides the opportunity to simulate warm-up and starting procedures of the gearbox.

Sensors for temperatures at different oil sump and bearing positions, as well as pressure sensors, measure useful

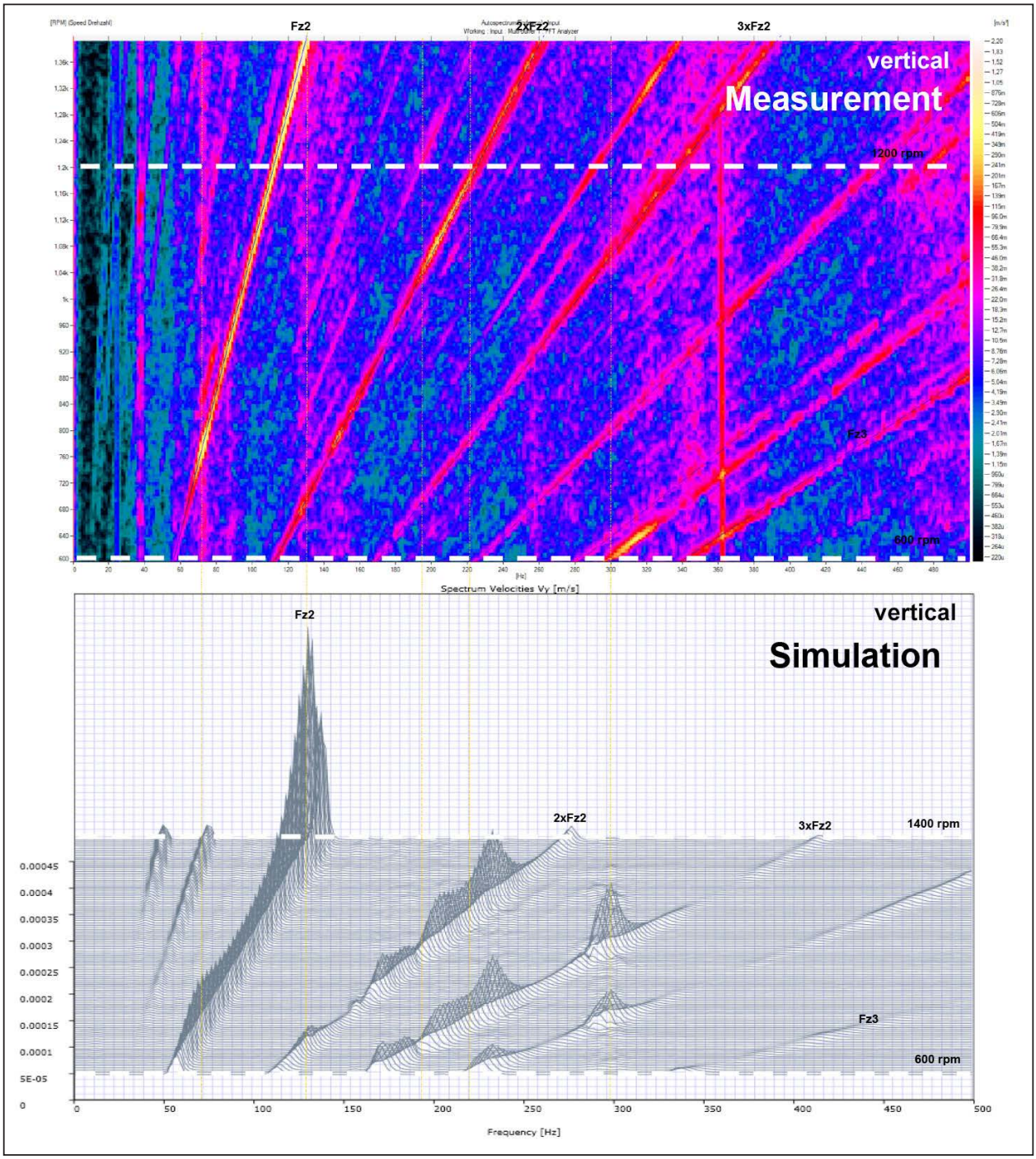

Figure 6 Comparison of the structural accelerations at the torque arm between measurement and simulation during a run-up of the test rig (solid-borne vibration).

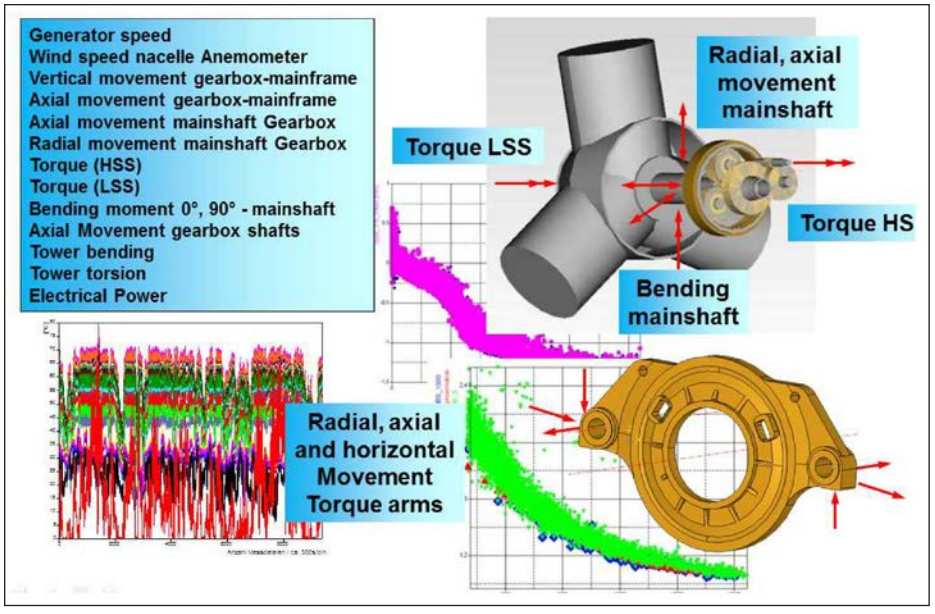

Figure 7 Sensor positions and signals for a field validation measurement.

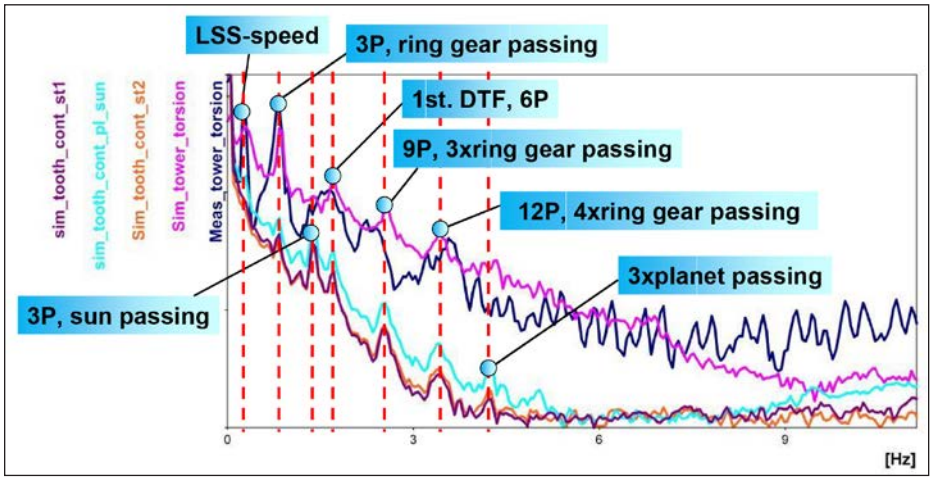

Figure 8 Comparison of frequencies included in stress signal of tower torsion based on measured and simulated data frequencies are derived from time signal of tower stress in upper-third of the tower by a fast Fourier transformation approach.

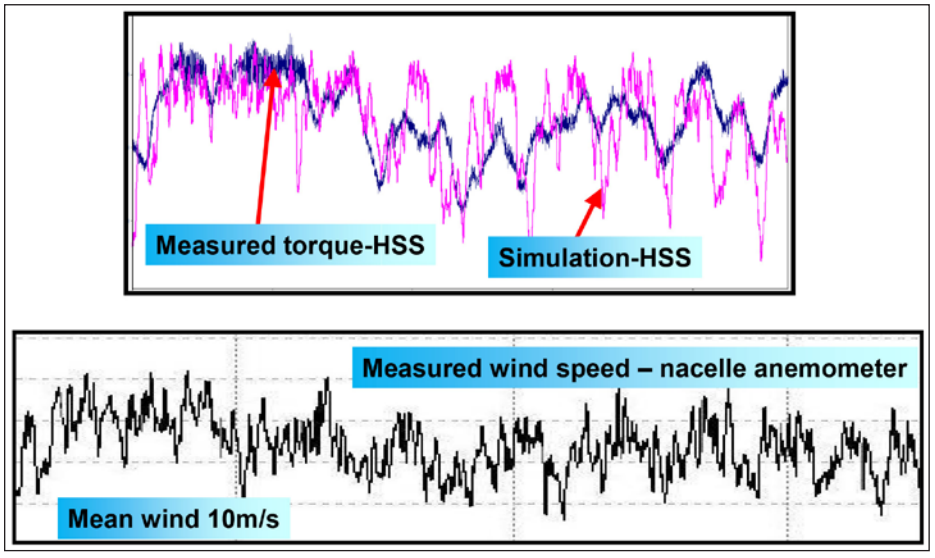

Figure 9 Comparison between a measured and simulated torque moment on the high-speed shaft of the gearbox; they are based on the same measured wind speed.

data that can be used to optimize the warm-up procedure and components of the lubrication system.

The optimization of the warm-up period between low reference temperature (–40°C) and the start temperature of the gearbox (0°C) increases the availability of the turbine and, as a consequence, the gain out of production.

The test rig has the capability to freeze the gearbox down to a temperature of -40°C and to start the gearbox under full load, offering the opportunity to obtain the initial breakaway torque of the frozen gearbox at the low-speed side of the gearbox. Those values are realistic compared to the situation on the wind turbine.

The simulation of different warm-up procedures with and without idling gearboxes is important to prove the suitability and performance of the operation strategy; emergency lubrication can be checked with different temperatures.

A procedure known as the "Melk test" verifies the required, specific oil quantities for toothings and bearings; volumetric measurements confirm the oil quantities at each nozzle point of the lubrication system.

Test Rig Verification — Acoustics and Dynamics

In most cases the input torque of an application is the design driver for gearboxes and other drivetrain components. The most common and typical values for the analysis and verification of simulation results are different shaft torques and frequencies that can lead to high accelerations within resonances.

Key issues within the design loops are stimulus and natural frequencies (Campbell diagram), transient time series for torque, bending and displacements at significant locations. Waterfall diagrams of signals measured during test rig start-ups are a common basis for resonance analyses, compared with the Campbell diagram.

Campbell diagrams are well-used tools for analyzing the resonance behavior of drivetrains. They contain information about natural frequencies, stimulus frequencies (even for different tooth numbers of different gearbox

versions), areas of operational speed, and torque. Critical operational speed areas — such as important points for noise and vibration — can be located. Today wind turbine manufacturers require low noise and vibration levels for the gearbox. Hence it is important to identify a close harmony between structural resonance, load-dependent tooth stimulus levels, and the inner dynamic behavior of the gearbox. The implementation of FEA super elements into the simulation model of a gearbox allows validation of the simulation results at positions for solid-borne sound measurement sensors.

The resonance points in Figure 6 are comparable between measurement and simulation. This analysis allows making conclusions and decisions for design loops based on simulation results for parameter variations. This will be beneficial with respect to safe hardware time on the test rig. After full validation of the gearbox the implementation of the gearbox model into a full wind turbine model will lead to reliable simulation results. These results provide a good basis for the optimization of the full wind turbine drivetrain.

Field Validation and Field Measurement

Validation of the gearbox within the actual turbine environment in the field is vital in confirming design assumption. That kind of validation measurement is the basis for a series of design evaluations, such as:

- Confirmation of design assumptions (deflections, movements, loads, bending, etc.)
- Acoustics and vibrational behavior (test rig and turbine environment)
- Validation of simulation models and results (test rig and turbine environment)

To receive answers for all of those questions, a large sensor set-up on the tower is necessary (Fig.7).

All of the time series that are measured during the measurement campaign can be used to validate design assumptions and to verify simulation models and their simulation results. The validation of simulation models is one of the most important tasks within the whole simulation and modeling process.

A comparison between *FLEX5* results, measuring results (test rig and field), and the results from advanced multi-body models is necessary in assuring the validity of the simulation results. The mode shapes of the turbine — as well as the calculated and measured time series — are used as primary validation data.

Figure 8 shows a comparison of frequencies that are included in the stress signal of the tower torsion based on measured and simulated data. The frequencies are derived from the time signal of the tower stress in the upper-third of the tower by a fast Fourier transformation approach. There are several frequencies, such as LSS rotation, 3xLSS rotation, 1st drivetrain frequency, etc., that occur in the tower stress and fit between the measured and simulated data. In addition to that, there are kinematic frequencies that occur in both signals. The occurrence of the most frequencies in the forces of the tooth contacts in each gearbox stage are a sign for the strong interaction and coupling between parts of wind turbines.

The control of the turbine and the model for the transformer both have a significant impact on the dynamic behavior of the wind turbine. To assure the correct functionality of the control model within the simulation model, suitable measured validation data must be collected. In most cases (rough wind and high grades of turbulence) the wind speed at the anemometer of the nacelle is not feasible as input data for a simulation that should be used as validation basis. As a result of the rotor impact, the wind speed in front of the rotor and behind the rotor is different.

With intermediate wind speeds and less turbulence, it is possible to find wind speeds sampled by the nacelle anemometer that are suitable to be used as input parameters for the simulation.

Figure 9 shows a comparison between a measured and simulated torque moment on the high-speed shaft of the gearbox; they are based on the same measured wind speed.

The measured time series of the wind speed behind the rotor is used as input for the simulation as one dimensional transient wind field that attacks the rotor in its center point.

The time-based signal of the measured HSS torque fits to the signal of the measured torque; it can be concluded that the embedded model for the controller works comparably to the real system.

In addition to loads, displacements of drivetrain parts are important validation criteria. In some cases displacements are more sensible against inaccurate coupling properties for stiffnesss within the model than loads. Hence it is also important to compare measured and simulated displacements of drivetrain parts. **PTE**

Dr.–Ing. Frank-D. Krull has been with Eickhoff Antriebstechnik GmbH since 2001, and is currently head of its R&D department. He was educated at Ruhr-Universität Bochum: Maschinenbau / Kfz-Technik / Getriebetechnik (1990-1996), receiving his PhD in 2001 at Ruhr-Universität Bochum Steifigkeit, Dämpfung und Reibung an Kontaktstellen der Kolben von hydrostatischen Axialkolbenmaschinen. Krull is active in various capacities with such organizations as the Expert Group of Germanischer Lloyd; Working Group"Schmierstoffe und Tribologie FVA"; IEC 61400-4 Joint working group – Speaker of Germen Delegation; and the IEC 61400 CAC-OEM Subcommittee.

Load Capacity and Efficiency of Grease-Lubricated Worm Gears

Prof. Dr.-Ing. Karsten Stahl, Prof. Dr.-Ing. B.-R. Höhn, Dr.-Ing. Michael Otto and Dr.-Ing. Alexander Monz

Varying installation requirements for worm gears, as, for example, when used in modular gear systems, can necessitate grease lubrication — especially when adequate sealing for oil lubrication would be too complex. Such worm gears are being increasingly used in outside applications such as solar power plants and slew drives. While knowledge about the operating conditions is often appropriate, the basic understanding for load capacity and efficiency under grease lubrication is quite poor. Investigations done at FZG and sponsored by FVA/AiF are shown here to give an impression of the basic factors of load capacity and efficiency. The results of the investigation indicate a satisfying quality of calculations on heat, load capacity and efficiency based on characteristic parameters of the base oil with only slight modifications to the methodology known from DIN 3996 or ISO TR 14521.

Introduction

Regarding some of a worm gearset's basic properties — high achievable gear ratio including the potential of self-locking — it seems quite worthwhile to use them in applications where the basic disadvantages — for lower to medium sizes primarily wear and a complex efficiency — are of minor importance. Worm gears are appropriate in applications absent high shaft speeds; should there be a need for easy sealing, lubricating the worm gearset with greases of higher viscosity (NLGI 2) will become increasingly attractive. Greases, on the other hand, deal with two major disadvantages — 1) a rather bad heat transfer, and 2) absence of cleaning efficiency. Therefore a precise knowledge of load capacity — especially of heat transfer and wear, as well as general information on appropriate greases — was subject to systematic verification. In this context results of worm gearsets with a center distance of $a = 65$ mm are shown to demonstrate the methodology and to indicate promising approaches for future investigation. Another experiment with a cast iron worm wheel indicates potential for greater optimization.

State of the Art

Calculating heat transfer in worm gears is based on the investigations of Neupert (Ref. 1) at stationary conditions that were included in the calculation method according to DIN 3996:2012-09 (Ref. 2). An approach for transient conditions was done by the analysis of Hermes (Ref. 3). Nevertheless all methods consider oil as a lubricant, resulting in consideration of the lubricant being of uniform temperature.

The calculation of wear is also based on the analysis of Neupert (Ref. 1) and has been sub-

Figure 1 Electrically braced test rig at FZG.

Table 1 Basic data for test gears

	Worm	Worm wheel
Material	16MnCr5	CuSn12Ni2-C-GCB
Number of teeth z	2	41
Flank form	I	
Module m	2.5 mm	
Quality	5	6
Heat treatment	58-62HRC, eht 0.4mm	
Roughness Ra	0.3 - 0.5 µm	

Table 2 Basic data for lubricants

Name	Viscosity @40°C [mm²/s]	Viscosity @100°C [mm²/s]	Thickener	Percentage of thickener	NLGI	Additive
Polyglycols						
PG1	131	21	Li	8	2	AO,EP
PG2	220	46	LiK	12	2	AO,EP
PG2-GÖ	220	46	-	-	-	
Mineral oils						
MIN1	220	16	LiK	14	2	AO,EP

This paper was first presented at the 2013 VDI International Conference on Gears, Technical University of Munich, Garching, Germany, and is reprinted here with VDI permission.

jected to several elaborations by, for example, Weisel (Ref. 4), Hermes (Ref. 3), Jacek (Ref. 5) and Nass (Ref. 6). The method is based on a specific wear-intensity-per-sliding-distance, taking into account material, type of oil lubrication, and type of oil, as well as basic operating conditions. Specific values for grease as a lubricant do not as yet exist. The calculation of efficiency as indicated (Ref. 2) is drawn from a base coefficient of friction considering the same influencing factors as for wear. Since all results showed the assignability of these methods, corresponding factors for grease lubrication were defined to be adaptable, as found in Reference 2).

Test Stand Operations

The tests were carried out with a center distances of $a = 65$ mm, but with different greases. Figure 1 shows the used, electrically braced, test rig. Input/output torque, input speed and mass-temperature were measured continuously, as was the wear rate at given numbers of load cycles. The tests were done as load stage tests at different speeds. Cylindrical worm gears according to Table 1 were used.

Table 2 shows the matrix of the tested greases. In total, 21 greases with 12 corresponding base oils were tested, with compositions including polyglycols, polyalfaolefins, and mineral oils. In this paper, basically results of MIN1 and PG2 — both sharing the same additive packages and thickeners — will be discussed. Additional lubricants are grease PG1 and PG2's base oil. Additional information can be found in Reference 7.

Test Results

Heat transfer. It is commonly known that greases do not display the thermal behavior of oils. Oils show uniform temperatures at a time being constantly agitated and thus transferring heat from the source to the housing by convection. Unlike that, NLGI-2 greases are conducting the heat.

Figure 2 shows the heat gradient in axis section of the worm, caused by a power loss of 218 W at 150 rpm at the worm. The mass temperature of the worm, being 110°C drops at a rate of almost 1°/1 mm.

The major factor to mass temperature is the power loss of the teeth. With a decreased ability of grease to transfer the heat to the housing, mass temperature under grease lubrication is significantly higher than the temperature of splash oil lubricated worm gears. By comparing temperatures of both oil and grease lubricated operational states with the same power loss, Figure 3 shows this fact. It can be seen, that the temperature of grease lubricated gears is approximately 10 to 20°C higher.

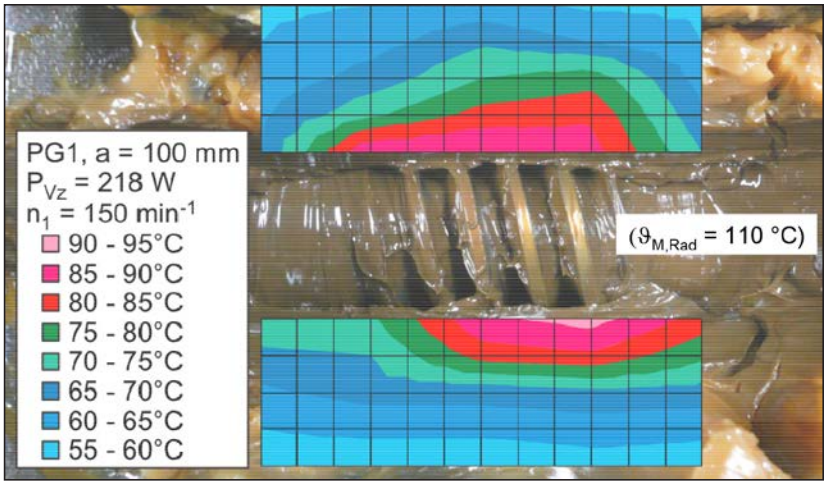

Figure 2 Heat gradient inside gearbox at worm section.

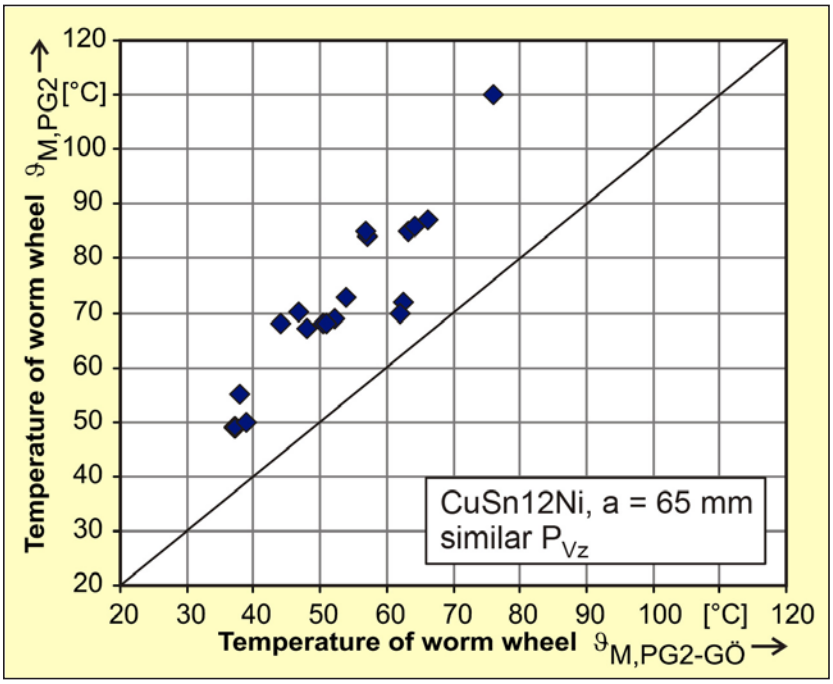

Figure 3 Mass temperature at same power loss for oil and grease lubrication.

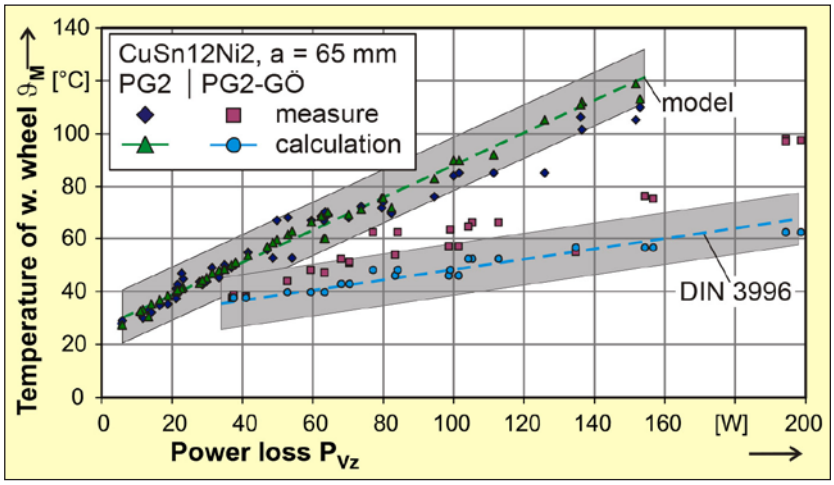

Figure 4 Mass temperature as function of power loss (grease PG2 and oil PG2-GÖ).

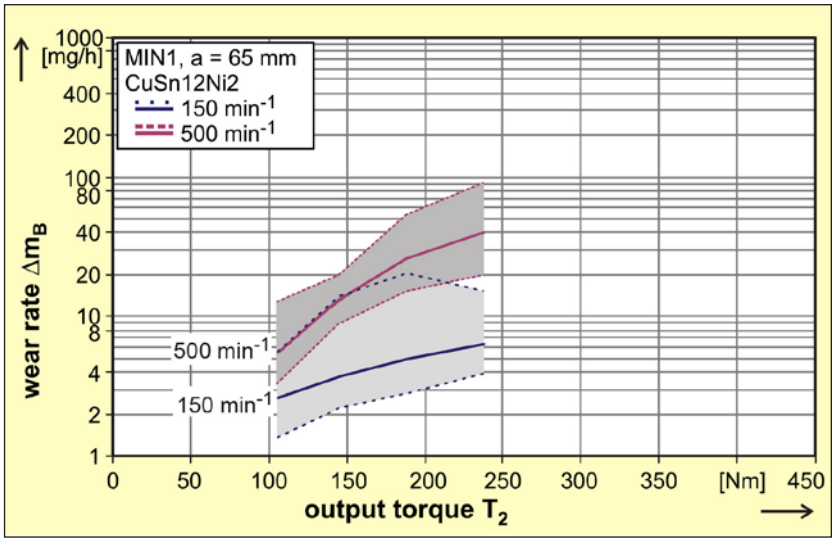

Figure 5 Wear rate for grease MIN1.

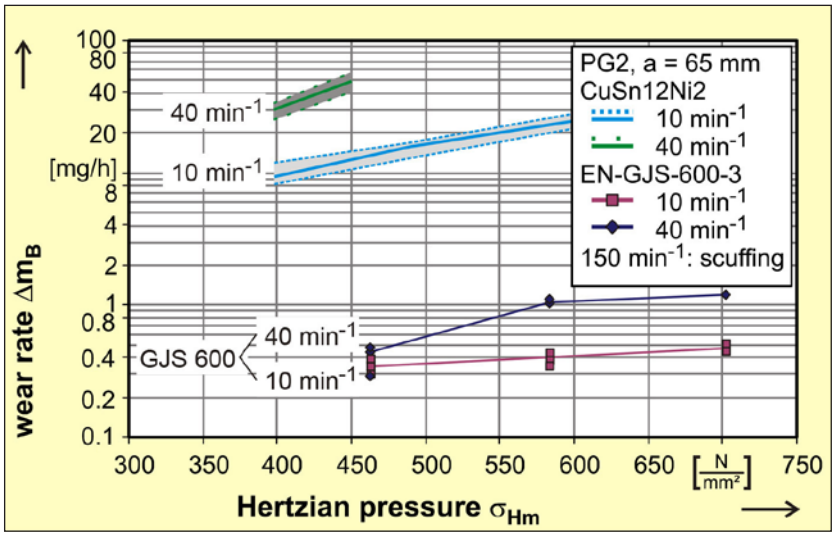

Figure 6 Wear rate for grease PG2, bronze and cast iron.

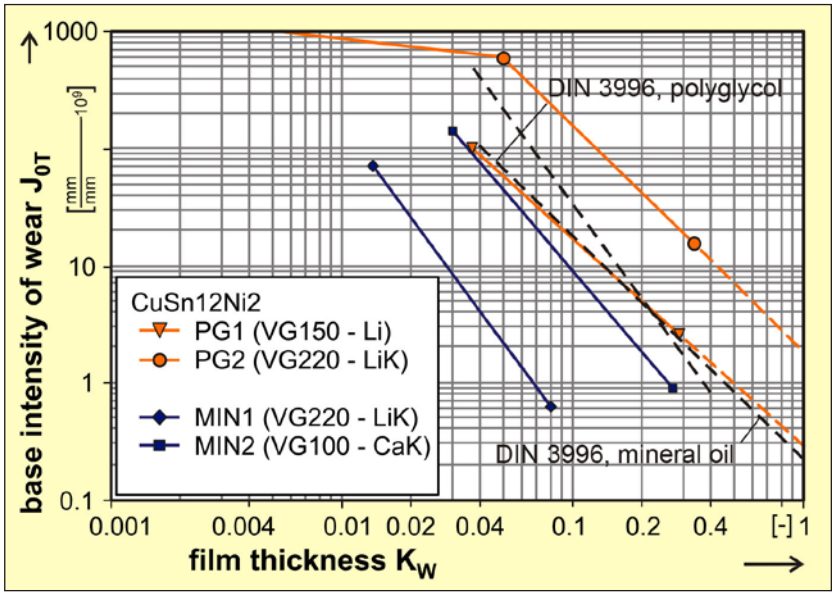

Figure 7 Base intensity of wear — all greases.

Figure 4 shows the comparison of mass temperature for oil and grease lubrication to a corresponding calculation model. While calculation with DIN 3996 (Ref. 2) shows a slight deviation from the measurements, a thermal homologous model calculating conduction over every element of the gearbox shows rather good concurrence. Thus an evaluation of mass temperature as the relevant temperature to calculate EHL film thickness is enabled.

Load Capacity

Figure 5 shows the wear rate in mg per hour as a function of output torque and input speed for grease MIN1 at stationary operating conditions. The results respond to characteristics similar to those of oil lubrication but including a rather high variance. This variance in wear rate is corresponding to a rather high variance in mass temperature. It is quite obvious that a real "steady state" is not reached as a raise and fall of mass temperature still can be found after more than twenty hours of running. The level of wear rate is quite high especially compared to oil lubrication.

Apparently, input speeds of 150 or 500 rpm lead to rather high wear rates. Slower speeds such as 10 or 40 rpm on the other hand show significantly lower wear. A change of the worm wheel material from bronze to cast iron shows significant improvements. Due to scuffing, higher speeds above 150 rpm weren't operable. Nevertheless, variance is much smaller than at higher speeds (Fig. 6).

To enable calculation of wear load capacity, the base wear rate J_{0T} is defined by the results. This method allows comparison of various lubricants — regardless of geometry and operating conditions — and based simply on a specific parameter representing the film thickness. Figure 7 shows these results for the greases MIN1, PG1 and PG2 — all based on Li or LiK-thickener. In addition, grease MIN2 is shown using CaK as a thickener and showing additional improvement of wear characteristics. The greases based on mineral oils show significantly better wear performance than calculated with DIN 3996 (Ref. 2) for oils.

Efficiency

Figure 8 shows the base coefficient of friction for grease PG2, its base oil PG2-GÖ, and the reference according to DIN 3996 (Ref. 2) as a function of mean sliding velocity. It was determined and duplicated that the grease is showing lower values at lower sliding speeds, as demonstrated in the reference.

Conclusion

- It has been proven that under specific operating conditions — especially when using low input speeds — greases may show lower wear rates than corresponding oils, as well as lower base coefficients of friction.
- Regarding the broad variety of lubricants that were subject to investigation (Ref. 7), grease MIN1 (LiK) happens to be a good compromise between wear and efficiency (Fig. 9)
- Taking MIN1 as a starting point, grease MIN2 (CaK) shows better wear characteristics, but higher friction coefficients and a smaller band of service temperature.
- Focusing on efficiency PG2 (LiK) proves to be the better choice, offering even less friction than MIN1. **PTE**

References

1. Neupert, K. Verschleisstragfähigkeit und Wirkungsgrad von Zylinder-Schneckengetrieben. Diss., TU München 1990.
2. DIN 3996: Tragfähigkeitsberechnung von Zylinderschneckengetrieben mit Achswinkel Σ = 90°. Deutsches Institut für Normung e.V. 2012.
3. Hermes, J. "Tragfähigkeit von Schneckengetrieben bei Anfahrvorgängen Sowie Astund Drehzahlkollektiven," Diss., Ruhr-Universität Bochum 2008.
4. Weisel, C. "Schneckengetriebe mit Lokal Begrenztem Tragbild," Diss., TU München 2009.
5. Jacek, A. "Tragfähigkeitssteigerung von Schneckengetrieben durch Optimierung der Schneckenradbronze," FVA-Forschungsvorhaben 205/II, FVA-Heft 631 2001.
6. Nass, U. "Tragfähigkeitssteigerung von Schneckengetrieben durch Optimierung der Schneckenradbronze," FVA-Forschungsvorhaben 205, FVA-Heft 476 2001.
7. Monz, A. "Tragfähigkeit und Wirkungsgrad von Schneckengetrieben bei Schmierung mit konsistenten Getriebefetten," Diss., TU München 2013.

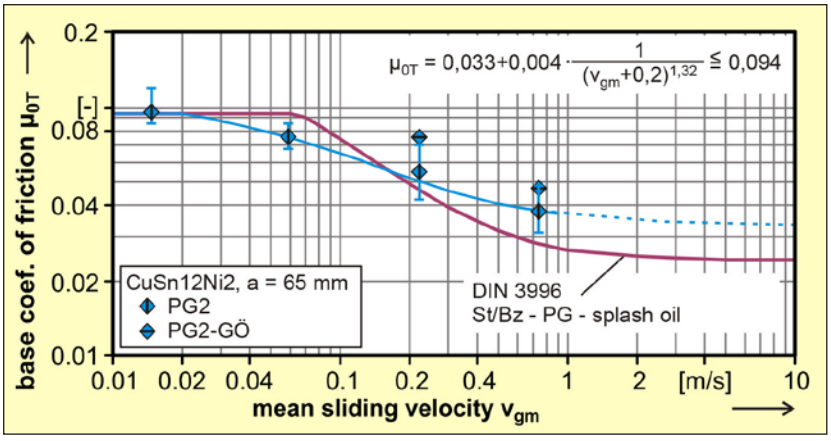

Figure 8 Base coefficient of friction for grease PG2 and corresponding base oil.

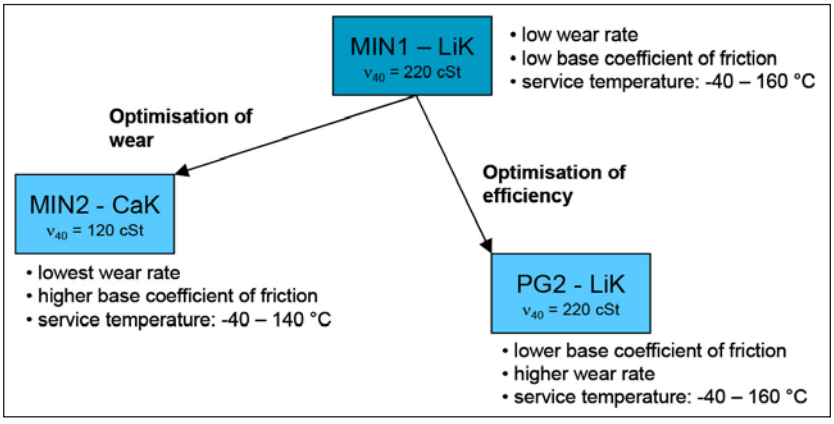

Figure 9 Potential for optimization.

Bernd-Robert Höhn studied mechanical engineering at the Technical University Darmstadt (1965-1970) and served as an assistant lecturer (1970-1973) at the Institute for Machine Elements and Gears at the Technical University Darmstadt prior to becoming an assistant professor at the university (1973-1979); in 1978, he received his PhD (Dr. Ing.) in mechanical engineering. In early April, 1979 Höhn worked as a technical designer in the department for gear development of the Audi, and by 1982 was head of the department for gear research and design for the automaker. In 1986 Audi named Höhn department head for both gear research and testing of automotive transmissions, until his departure in 1989 to become head of both the Institute of Machine Elements at the Technical University and of the Gear Research Centre (FZG). Höhn has served since 2004 as vice president for VDI for research and development and since 1996 has led the working group 6 and 15 for ISO TC 60 — calculation of gears.

Dr.-Ing. A. Monz studied mechanical engineering at the Technische Universitaet Muenchen, while also serving as a research associate at the university's Gear Research Centre (FZG). In 2012 he received his PhD degree in mechanical engineering and that same year was hired as R&D manager at the IMO Group in Gremsdorf, Germany. He subsequently moved on to the Schaeffler Group in Herzogenaurach, Germany, working there until 2013 as a specialist in advanced engineering for synchronizers. In 2014 Monz returned to IMO Group as deputy head of engineering.

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Back to Work

By Brian Langenberg, CFA

Little has changed since our prior installment, "DAS (HUMAN) KAPITAL," which is to say August is a slow month with very few reads from companies.

Kennametal reported 5% core order growth for three months ending July 31, the sixth straight month of positive growth. Is this meaningful? Our Kennametal orders analysis indicate easy comparisons should drive positive "growth," at least through October, but growth against weak comparisons isn't really growth. Sometimes, in order to get the right perspective, you have to take a wider view of the situation (see Figure 1). As we wrote in our blog (*thefirstshift.langenberg-llc.com*), a few points stand out:

1. Kennametal core orders went negative in mid-2012 until October 2013.
2. The positive comparisons since February are "comparison" driven, not really growth.
3. Real demand remains well below peak.

Aerospace, automotive and truck markets remain positive, but we are seeing continued deterioration in agricultural equipment (lower production and layoffs at Deere).

The reality of current and near-term demand growth was borne out in last quarter earnings releases where several heavy machinery companies missed forecasts (Fig. 2).

Manufacturers of construction equipment, in particular, continue to see "just in time and just enough" buying behavior from rental houses and E&C companies. The three big potential drivers, along with our outlook:

- Highway Bill – unless 10-15 bridges collapse, nothing before '17.
- Non-residential Construction – ABI index consistently positive; expect some growth in '15.

Figure 1 Here is the wrong way to study orders and sales trends.

- Power Generation – weak electricity demand, regulation = little US activity except wind.

Updated views on end markets:

Oil & Gas: Offshore should accelerate in (late) 2015, possibly closer to 2016. Closer to home, midstream expansion continues to support upstream production (from hydraulic fracturing) to refineries and increasingly exports (condensate recently approved).

Mining: Still wretched, but the worst is over. Don't expect a rapid upturn given awful coal market conditions exacerbated by weak China demand for iron ore, coal and capital. Offsetting these challenges are capacity cuts and narrowing losses at some miners.

Power Generation: No change. Wind is solid, natural gas up, coal dead.

Transportation Infrastructure: Stagnant.

Water & Environmental: Municipal budgets and tax receipts are funding catch-up capital spending, not real growth.

Machinery: Expect continued growth in truck, stability to modest growth in construction equipment and slowing agricultural equipment production.

Consumer (auto, appliances): Auto demand will remain strong, and improving home prices signal gradual improvement in construction equipment.

Aerospace/Defense: Commercial air transport remains strong, and the recent Farnborough air show yielded strong orders for Boeing, General Electric and United Technologies. Aftermarket activity remains robust. Defense related declines have moderated, and war is, unfortunately, not obsolete.

Focus Company: Atlas-Copco

Atlas-Copco is a premier industrial machinery company with extremely strong global market shares in industrial compressors, mining and rock project engineering, equipment, parts and service. Following the company gives us a great read on short-cycle and late-cycle activity as well as mining. Even better — we get geographic detail by segment.

Mining has proven a major sales drag. In 2Q it represented 27% of rev-

MACHINERY	TICKER	SURPRISE REV	SURPRISE EPS	STOCK STK	STOCK MKT	CONSENSUS REV	CONSENSUS EPS	ACTUAL REV	ACTUAL EPS
Caterpillar	CAT	(2)	+11	(2)	+0	14,450.0	1.52	14,150.0	1.69
Manitowoc Company	MTW	(4)	(17)	(13)	(1)	1,050.0	0.42	1,013.0	0.35
Terex Corporation	TEX	+5	(6)	(9)	+0	1,960.0	0.81	2,055.1	0.76
Oshkosh Corporation	OSK	+1	(10)	(10)	+0	1,920.0	1.37	1,930.0	1.23
United Rentals	URI	+3	+15	+6	+0	1,358.0	1.43	1,399.0	1.65
Cummins	CMI	+0	+2	(3)	+0	4,820.0	2.39	4,835.0	2.43
PACCAR	PCAR	+4	+1	+2	+0	4,410.0	0.89	4,570.0	0.90
Sandvik	SDVKF	(1)	(8)	--	--	22,250.1	1.32	22,051.0	1.22
SKF	SKFB.SS	+1	(13)	--	--	17,836.0	2.93	17,955.0	2.54

Source: Langenberg & Company

Figure 2 A number of heavy machinery companies have missed their forecasts recently.

enue and fell (19%) year over year but rose 2% quarter over quarter. On the positive side, orders are finally stabilizing, albeit at a low level. This is consistent with our views on mining.

The $64,000 question remains late-cycle, heavy capital investment that supports demand for construction equipment and heavy machinery. Consistent with our Kennametal commentary, the picture is mixed.

Here is what we gleaned from the Compressor Technique segment.

- Small- and medium-size compressor orders have remained in a modest uptrend. These are a good read on short-cycle industrial (maintenance capital spending, replacement demand).
- Larger machine orders fell for the 5th straight quarter. Market remains dead.

Multiple headwinds. China is rooting out corruption, which means decision makers are running scared, not ramping big projects. Latin America is off, and both Europe and the Middle East have war on their hands.

The best growth market, perhaps in spite of ourselves, is the United States. **PTE**

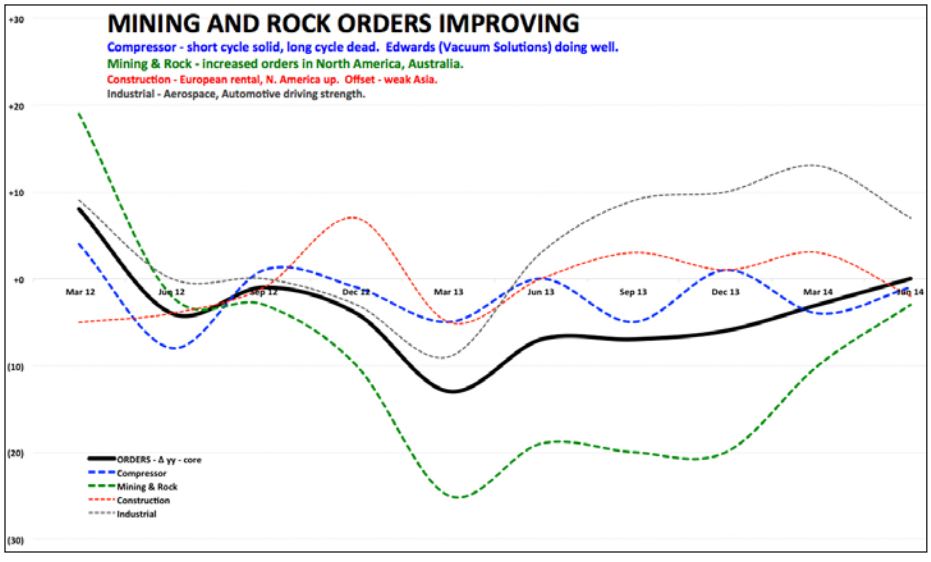

Figure 3 Mining and Rock Orders Improving.

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Brian K. Langenberg, CFA, has been recognized as a member of the Institutional Investor All-America Research Team, a *Wall Street Journal* All-Star, and *Forbes/Starmine* (#1 earnings estimator for industrials). Langenberg speaks and meets regularly with CEOs and senior executives of companies with over $1 trillion in global revenue. His team publishes the *Quarterly Earnings Monitor/Survey*—gathering intelligence and global insight to support decision-making. You can reach him at *Brian@Langenberg-llc.com* or his website at *www.Langenberg-LLC.com*.

Timken Canada

RE-LAUNCHES PARTNERSHIP WITH GARLOCK SEALING

Timken Canada has announced that it is re-launching the partnership with Garlock Sealing Technologies (an EnPro Industries Company) to more aggressively pursue sales of their oil seal and bearing isolator products. The announcement was made at a customer dinner event in Quebec City last month. Frank Mascia – managing director of Timken Canada described the fit that Garlock product has with the portfolio of bearing and PT products currently offered and Mike Monica, Garlock's director of global sales emphasized the synergies to be recognized between the two organizations.

Mike Monica with Barb Ross from Garlock Sealing Technologies (courtesy of Timken).

While Timken has been modestly selling Garlock product since 2006, the market is now seeing the benefit to a rationalized supply base and the technical support that Timken technical sales representatives can provide. Timken now has an extensive domestic inventory of seals and isolators, supported by Garlock's manufacturing base located in Palmyra, NY.

Premium Seals, such as the Model 64, is an assembled seal (vs bonded), with a heavy duty metal outer case and a garter spring held in place with a stainless steel finger spring. It is available in three different Mill-Right elastomer materials. The popular Guardian Isolator is a bronze labyrinth non-contacting seal that is easy to install.Non wearing components provide significantly extended equipment life.

Cummins Inc.

CELEBRATES 40TH ANNIVERSARY OF JAMESTOWN PLANT

Cummins Inc. recently celebrated the 40th anniversary of its Jamestown Engine Plant (JEP) in Jamestown, N.Y. Typically, more than 400 engines are built per day at JEP, and the plant produced its 1.5 millionth heavy-duty engine in the summer of 2013. Each of the plant's engines meets the emissions regulations in every part of the world to which they are shipped.

"The Jamestown Engine Plant plays a critical role in our company's ability to produce a broad range of diesel and natural gas engines for different customers around the world," said Dave Crompton, president - Cummins Engine Business. "This anniversary is a testament to our more than 1,500 employees at JEP who produce reliable, clean and fuel-efficient engines that enable our customers to be successful in all of the markets they operate."

Cummins acquired the more than 1-million-square-foot facility in 1974, using it initially to manufacture engine components. The plant produced its first engine in 1979. Today, it builds on-highway engines, including the ISX15 - the top-selling heavy-duty truck engine in North America - as well as the ISX12 and ISM diesel engines. The ISX15 and ISX12 engines both serve the U.S. and Canadian markets, while the ISM is currently exported to Mexico. JEP also produces the Cummins Westport ISX12 G spark-ignited natural gas engine.

Engines produced at JEP power numerous types of applications, from line-haul trucks to RVs and even fire trucks. In addition to these on-highway applications, JEP also produces the QSM and QSX engines that serve off-highway customers in construction, agriculture and marine applications.

The plant also plays an important role in improving life in western New York. It's the largest private employer in Chautauqua County and the largest contributor to the local United Way. JEP is also an active participant in Cummins Every Employee Every Community program, which allows employees to work at least four hours per year on a public-service project on company time.

"We take Cummins commitment to community service and improving the communities in which we live very seriously," said Mike Abbate, JEP plant manager. "I'm tremendously proud of what our employees are doing inside and out of our plant to make western New York a better place to

live. This anniversary is a great time to celebrate and salute their many contributions to our company and the community. We owe gratitude to our former and current employees, who have been and continue to be the reason why we are a successful company."

Crompton said plants such as JEP play an integral role in Cummins efforts to bring to its customers the most innovative solutions to their power needs. "JEP was founded on a unique team-based system, which continues to be a competitive advantage for us, and it's a quality our employees embrace," said Crompton. "The highly-skilled men and women at JEP and our plants around the world make innovation a reality. An anniversary such as this is just another indicator of their commitment to quality. They help Cummins deliver the best solutions to our customers every day."

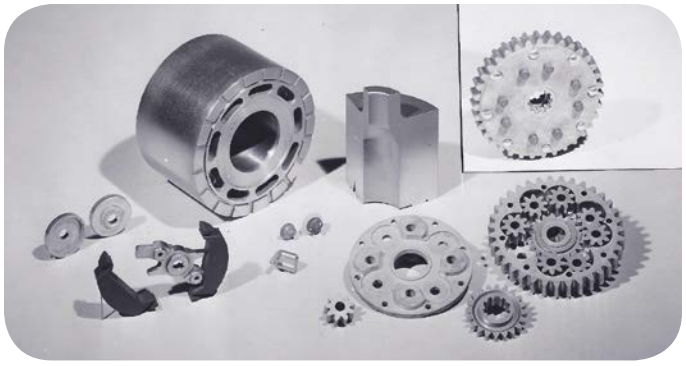
MPIF

CELEBRATES 50 YEARS OF PM DESIGN

An event that took place without much fanfare at the 1965 International Powder Metallurgy Conference held at New York's Statler Hilton Hotel was the presentation of the awards to winners of the first design competition, called the "P/M Part of the Year," sponsored by the Metal Powder Industries Federation. From that humble beginning, over the succeeding five decades the competition has evolved into a prestigious event recognizing achievements in state-of-the-art design of components fabricated through powder metallurgy (PM).

In the process, the competition has helped promote the capabilities of this emerging technology worldwide, which was the true purpose of its creation. By today, the competition, since renamed the "PM Design Excellence Awards," and the presentation of the winners have come to serve as a major component of the annual conference, with the special awards luncheon becoming a highlight attraction, and the physical display of the parts in the exhibition hall a consistent draw for attendees.

In the historical catalog of its award winners, one may trace the development of PM into the broadly accepted fabrication technology it is today, with milestones in applications and manufacturing methods clearly delineated. The occasion of the competition's 50-year anniversary is a propitious opportunity to look back at the path PM has traveled while simultaneously contemplating its future direction.



To mark the 50th year that the MPIF has held a competition for excellence in part design, a display featuring a 50-year timeline was produced at the PM2014 World Congress. The timeline has been reproduced for display on the website (*www.mpif.org*).

NSK Europe

APPOINTS MANAGING DIRECTOR

Michael Preinerstorfer is the newly appointed managing director of NSK's European Industrial Business Unit (EIBU). The world's third-largest manufacturer of bearings has centralized its European activities - in the field of bearings and linear technology - for industrial applications in this Ratingen-based business unit.

Preinerstorfer (44), a qualified engineer originally from Austria, studied metallurgy at the University of Leoben. In 1997, he gained his first professional experience with his involvement in research and development for a tin producer in Malaysia. In 1998, he took a position as project engineer at a German plant belonging to the British IMI Group, which is very successful in various areas of fluid handling.

At IMI, Preinerstorfer was active in various Group companies and positions, including as managing director of IMI Norgren Buschjost, managing director of Heimeier GmbH and most recently as vice president of European sales at TA Hydronics.

Jürgen Ackermann, CEO of NSK Europe Ltd.: "I would like to welcome Michael Preinerstorfer into his new role at NSK. As Managing Director of EIBU, his responsibilities will include further expanding NSK Europe's technological leadership and increasing the company's European footprint."

The European Industrial Business Unit produces bearings and linear technology systems at five European locations. At its European Technology Centre in Ratingen, which employs 180 people, the company offers demanding customers outstanding opportunities for the joint development and testing of drive system components. In total, NSK – including its

automotive business – has five production facilities and approx. 4,500 employees in Europe, where it generates more than €900 million in sales.

NFPA

LAUNCHES EDUCATION AND RESEARCH SOCIETY

The NFPA Education and Technology Foundation recently launched a new annual giving society to increase support for fluid power education and research. Named after Blaise Pascal, the French mathematician, physicist and inventor whose famous law describes the fundamental principle that gives fluid power its force multiplier effect, the Pascal Society will combine the financial and volunteer contributions of companies across the supply chain to create a similar effect for the fluid power industry.

"NFPA members consistently rank the education of a well-prepared workforce as the number one challenge they face in growing their businesses and bringing new products to market," said Eric Lanke, CEO of the National Fluid Power Association. "And so we are very excited to be launching this effort within the NFPA Foundation. The Pascal Society will provide a way to not only increase our support of fluid power education and research activities but, through a connection to the CCEFP, the Society will increase the number of productive partnerships between industry members and universities."

The Center for Compact and Efficient Fluid Power (CCEFP), is a network of fluid power research laboratories, academic faculty, graduate and undergraduate students at seven U.S. universities. Since its inception in 2006, the CCEFP has engaged more than 6,000 university students in a variety of workforce development programs, including a series of pre-competitive fluid power research projects. Those projects, directed by industry to the topics most needed, have built new fluid power infrastructure at the CCEFP schools and have successfully engaged promising students in the study of fluid power. Forty-five percent of these students have gone on to work in the fluid power industry.

Professor Kim Stelson of the University of Minnesota is the director of the CCEFP. "Although we have been successful in connecting students to our own industry members, the new collaboration with the NFPA Foundation will significantly widen the pool of potential industry partners. What was a small inner circle of 15 or 20 companies can now grow towards the more than 300 companies that belong to NFPA and make donations to the NFPA Foundation. With these additions, we expect to broaden our university participation, bringing fluid power to more and more schools."

In this inaugural year, all of the existing and former members of the CCEFP have been invited to make contributions through the new Pascal Society instead of paying membership dues to the CCEFP. Those choosing to make the switch are being invited to serve on one of the industry leadership committees that will provide oversight and guidance to the pre-competitive research program of the CCEFP and some of the NFPA Foundation's other activities. For additional information, visit *www.nfpa.com*.

Designatronics

WELCOMES VP OF SALES

Earlier this year, Designatronics Incorporated announced that Jacques Lemire joined the company as vice president of sales and marketing and as a member of the executive team, reporting to CEO and President Robert Kufner. Lemire oversees strategic marketing direction, sales management, business development, innovation, and application engineering to help redefine the customer service experience and value proposition for Designatronics customers.

"Jacques shares our values and our focus on innovation and growth, and he places the same strong emphasis on customer experience that we do. He has shown himself to be an extraordinary leader throughout his career and has a proven track record," Kufner said.

"With over 25 years' experience in the aerospace/defense industry across the globe, I am looking forward to bringing the best sales and marketing practices and processes to Designatronics and its five divisions, in order to improve the company's success and leadership in a changing world," said Lemire.

Lemire joined the Designatronics team in February 2014 from LORD Corporation, where he held multiple global leadership positions in product innovation, engineering, sales, and marketing, leading the company to outstanding global growth. Prior to LORD, he was at Bell Helicopter Textron, and earlier in his career at Bristol Aerospace/Rolls Royce Canada.

C&U Group

EXPANDS TAPER ROLLER BEARING PRODUCTION

The C&U Group, parent company of North American subsidiary, C&U Americas, has announced a major expansion of its Taper Roller Bearing plant facilities and overall production capabilities at the company's Tainai complex, which is lo-

cated in the Fengxian District near Shanghai. C&U is China's largest bearing producer and one of the world's top 10 bearing manufacturers.

A key objective of the expansion is to help meet the demands of C&U's rapidly growing North American market. In making the announcement, William A. Childers, president of C&U Americas, noted, "The added capabilities of the Tainai facility are just what we need to keep pace with our successful growth in the U.S. market and aggressive plans to expand our bearing business throughout the entire NAFTA region."

C&U's Tainai facility was established in 2004 and started producing both single-row and double-row taper roller bearings in 2005. In 2012, a second plant was added and the facility began to incrementally increase bearing production capacity. Overall floor space has been increased by a factor of four from 3,799 square meters to 15,100 square meters. The production lines have been doubled, giving the ISO/TS16949 certified plant 18 operational lines. All of the new lines are fully automated.

The Tainai plant expansion is an ongoing process and more production lines will be added over the next five years. This will more than double the current capacity. When the expansion is completed, the plant will be operating a total of 39 production lines and delivering over 2,260,000 taper roller bearing units per month.

PTDA

WELCOMES SEVEN NEW MEMBERS

The Power Transmission Distributors Association (PTDA) recently welcomed seven new member companies. Distributor members include: Creswell Richardson (Chattanooga, Tenn.), a distributor of power transmission, electrical automation/panel building and mechanical/electrical engineered solutions. Powerhouse Industrial Supply Inc. (Springdale, Ark.), a distributor of plastic and stainless steel products.

Manufacturer members include Berliss Bearing Co. (Livingston, N.J.), a bearing and seal manufacturer. Donghua USA Inc. (Glendale Heights, Ill.), a chain manufacturer. Radicon USA (Elk Grove Village, Ill.), a manufacturer of gears.

Associate members include Coughlin Insurance Services (Larchmont, N.Y.), a privately owned, multi-location insurance brokerage, with operations in New York and California. DK Industrial LLC (Walpole, Mass.), provides marketing sales solutions programs within the power transmission distribution and manufacturing industry. For additional information, visit *www.ptda.org*.

PTDA
Channeling the Power of Industry

September 30—ABMA Bearing Materials Webinar. The American Bearing Manufacturers Association (ABMA) has opened registration for a bearing materials webinar. This webinar is designed to provide an overview of numerous issues related to materials from which bearings and their components are manufactured. This will include a general overview of the process of steelmaking and hot forming as well as a discussion of impurities which are common to all steels, and their influence on performance. The presenters will also go over the principal ways of adjusting the strength of the steel (such as hardening grades with martensitic and bainitic structure, as well as case hardened components). The webinar will conclude with a comparison of the effect of these variants on life of bearings in different service conditions. This course will be moderated by Greg Tinnell, senior vice president of human resources, and presented by Dr. Werner Trojahn, both of the Schaeffler Group. It will take place September 30th from 1:00 - 2:00 PM Eastern. For more information, visit *www.americanbearings.org*.

October 7–8—AWEA Offshore Windpower 2014. Sheraton Atlantic City Convention Center, Atlantic City, New Jersey. 2014 has become a turning point for the U.S. offshore wind energy industry. With projects in advanced stages of development, lease auctions in several states, and additional government funding for advanced technology demonstration projects, the U.S. offshore wind energy industry is picking up speed and momentum. The United States has a vast offshore wind energy resource and in early 2011, the U.S. Department of the Interior (DOI) and the U.S. Department of Energy (DOE) unveiled a coordinated strategic plan to achieve the deployment of 10 GW of offshore wind power capacity by 2020 and 54 GW by 2030. State and federal processes for developing offshore wind projects in the U.S. were well underway at the end of 2013, with 12 offshore wind projects in the proposal stage. These projects span 10 states off the east, west, Great Lakes and Texas coasts and represent over 5,000 MW of offshore development with turbine sizes ranging from 3.0 to 6.0 MW, along with a transmission project that could carry up to 7,000 MW. For more information, visit *www.awea.org*.

October 22–24—ASME DSCC 2014. Marriott Plaza Hotel, San Antonio, Texas. The Dynamic Systems and Control Conference (DSCC) is the showcase technical forum of the Dynamic Systems and Control Division (DSCD). It provides a focused and intimate setting for dissemination and discussion of the state of the art in dynamic systems and control research, with a mechanical engineering flavor. The 2014 DSCC technical program will cover the modeling, simulation, analysis, design, and control of dynamical systems. Topics will include control theory, industrial applications, and innovations in dynamical systems and control education. Technical themes for the conference—including advanced manufacturing, renewable and traditional energy, bioengineering and biomedical engineering, and cybersecurity for critical infrastructure—will be featured in special tracks. The program will include contributed sessions, invited sessions, tutorial sessions, special sessions, workshops, and exhibits. For more information, visit *www.asmeconferences.org*.

October 22–25—PTDA 2014 Industry Summit. Orlando, Florida. Join more than 550 delegates for a networking event from the leading distribution and manufacturing companies involved in the PTDA. The summit includes educational workshops, networking forums, one-one-meetings, social events and an optional golf outing. Mike Ditka will give a keynote presentation on "Attitude, Character and Enthusiasm," on Friday October 24.Alan Beaulieu will give a keynote address called "The Beaulieu Report" that provides an accurate and straightforward forecast of the PT marketplace. For additional information, visit *www.ptda.org*.

October 27–30—PTC MDA ASIA. Shanghai New International Expo Center, Shanghai, China. As the largest annual industrial event in power transmission and control in Asia and the second largest in the world, PTC includes themes of smart manufacturing, energy efficiency and environmental protection. The event will attract exhibitors from China, Germany, Italy, Korea, Turkey, Taiwan of China and other countries and regions. In the exhibition, the debut of new products will illustrate the integration and development of Industry 4.0, highlighting the utilization of eco-friendly materials. PTC ASIA 2014 is jointly organized by China Hydraulics Pneumatics & Seals Association, China General Machine Components Industry Association, Deutsche Messe AG and Hannover Milano Fairs Shanghai Ltd., which will share a total exhibition area of more than 80,000 sqm with ComVac Asia 2014 that will be held during the same period. For more information, visit *www.ptc-asia.com*.

November 2–5—Pack Expo International 2014. Chicago, Illinois. Decision makers from a broad range of industries come to Pack Expo International for the opportunity to talk shop with vendors and "think outside the plant." Corporate managers, engineers, sales managers, plant managers, manufacturers and production supervisors, brand and marketing managers, quality controllers, purchasers, research/development and package designers from across the U.S. and around the world find value in learning where their companies stand on the technology curve and how they can provide flexible options for their customers. For more information, visit *www.packexpointernational.com*.

November 14–20—ASME 2014 IMECE. Montreal, Quebec. The annual ASME International Mechanical Engineering Congress and Exposition (IMECE) is the premier global conference that focuses on today's technical challenges, research updates and breakthrough innovations that are shaping the future of engineering. The Congress convenes engineers, academics, scientists and technologists of all disciplines for the purposes of exploring solutions to global challenges and for the advancement of engineering excellence worldwide. Engineers have long contributed to human progress by solving complex challenges on a global scale. For more information, visit *www.asmeconfernces.org*.

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☐ WE DESIGN products with power transmission components in them. (16)
☐ Other (please describe) (15)_____

5 → What is your primary job function responsibility? (Check one)

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❑ Plant Engineering (2)
❑ Design Engineering (3)
❑ Marketing & Sales (4)
❑ Manufacturing Engineering (5)
❑ Purchasing (6)
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High-Tech Motors Evolving from PM Muck

University Lab's Motor Eliminates Pricey Magnets

We know them as "rare earth" metals used for permanent magnets. They are used in sophisticated, high-performance electric permanent magnet (PM) motors for a growing number of motion control applications, including precision-demanding aerospace and weaponry systems and electric vehicles. In truth, it is not so much their availability that is rare — although to some extent there's that. No, the rarity is reflected in their dear price.

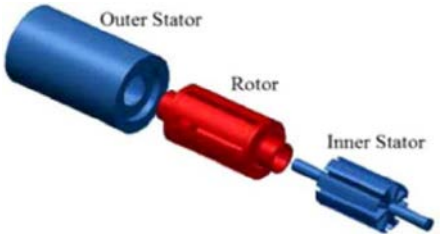
Indeed — isn't a more accurate name for these precious metals *dear earth* magnets?

What makes them rare, dear — whatever — is the fact that since 2010, U.S. purveyors of the stuff can no longer sustain supplying it. We left that up to — oh, you bet — *China* — who now of course controls the world's supply — pollution consequences notwithstanding. So any progress developing high-tech electric motors with similar capabilities — but sans those costly rare earth magnets — is most welcome.

Drum roll here please for Dr. Babak Fahimi, a University of Texas at Dallas (UT Dallas) professor of electrical engineering at the school's Erik Jonsson School of Engineering and Computer Science, and director of REVT (Renewable Energy and Vehicular Technology). He recently received $2.8 million through a Dept. of Energy (DOE) Advanced Research Projects Agency-Energy (ARPA-E) program aimed at reducing the need for rare earth metals (magnets) in electric motors. The DOE's ARPA-E program hosts an annual summit in Washington for researchers, entrepreneurs, investors, corporate executives and government officials to share transformational, pre-competitive research funded through the program. In addition to their award, Fahimi's REVT team was one of only five invited to actually demonstrate their work to lawmakers and participate in a roundtable discussion on climate change.

Thus far the government has sponsored as many as 10 ARPA-E-funded, high-performance no-magnet motor developments. Precipitated, many believe, when magnet prices were soaring and it became clear that that we no longer had any on-shore suppliers for rare earth magnets.

What in essence the UT Dallas REVT team has done is eliminate the need for permanent magnets (PMs) — *in some cases* — by substituting an SR (switched-reluctance) motor with two stators. Thus you can build a structure resembling a PM axial flux motor, but an SR motor and two SR stators replace the PM rotor and two stators. For more on this latest, evolutionary-but-not-quite-revolutionary step in motion control, we put some questions to aforementioned ARPA-E program member Dr. Fahimi.



The REVT Team's motor achieves higher-torque-per-Ampere, lower core losses, and better operation efficiency.

Power Play (PP): Eliminating the need for magnets seems like a *major* breakthrough — but way under the radar. Why has no one heard about it?

Babak Fahimi (BF): We are in the process of developing a 100-killowatt prototype of this concept that will be tested in the propulsion of a pick-up truck, and further tested in a compressor application in collaboration with an industrial partner. This partner is working very closely with us on integration of this concept for automotive and compressor applications, and we expect to launch the commercialization and marketing in 2015.

PP: Wouldn't NASA be deeply involved in something like this?

BF: NASA is interested in highly efficient electric motors that are compact; this technology, DSSRM, would address both, so we believe that NASA, or any industry that is seeking alternative solutions or highly efficient, fault-tolerant and compacts electric motors can take advantage of our technology.

PP: Can you tell me what other "transformational research" has over the years been successfully presented and implemented at the ARPA-E Summit?

BF: Our research presented at the ARPA-E Summit has been focused on DSSRM (double- stator switched-reluctance motor) technology.

PP: Is the Renewable Energy and Vehicular Technology Laboratory (REVTL) funded only by the DOE?

BF: No, others include the Office of Naval Research, the National Science Foundation, the Department of Energy, as well as many large and small businesses.

PP: How will the money award help further this project?

BF: This award has allowed us to modify the design for ease of manufacture, improving the performance and, most important, building prototypes at 2, 10 and 100 kilowatts. These prototypes have demonstrated or validated the results of our theory and analysis.

PP: How far away would you say the motor is from commercial availability?

BF: How far away depends on how industry would push this technology forward. The prototype alpha is already at hand, and we anticipate that by 2015-2016, the first products based on this technology to be available to this market. (Article Source: *newscenter@utdallas.edu.*)

PTE

(*The Power Play editors wish to thank* Dan Jones, *president of* Incremotion Associates Inc., *and a regular contributor to this magazine, for his assistance with this article.*)

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